CONCEPTUAL DESIGN STUDIES OF AN ADVANCED MARINER SPACECRAFT

Volume V

Development Plan And Cost

Prepared by

RESEARCH AND ADVANCED DEVELOPMENT DIVISION
AVCO CORPORATION
Wilmington, Massachusetts

This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, sponsored by the National Aeronautics and Space Administration under Contract NAS7-100.

RAD-TR-64-36
Contract 950896

28 October 1964

Prepared for

CALIFORNIA INSTITUTE OF TECHNOLOGY
JET PROPULSION LABORATORY
4800 Oak Grove Drive
Pasadena, California

217 PAGES
INCLUDES
(9 - ROMAN NUMERIAL)

RE-ORDER No. 64-52

This document consists of 218 pages, 250 copies, Series A

CONCEPTUAL DESIGN STUDIES OF AN ADVANCED MARINER SPACECRAFT

Volume V

Development Plan And Cost

Prepared by

RESEARCH AND ADVANCED DEVELOPMENT DIVISION
AVCO CORPORATION
Wilmington, Massachusetts

RAD-TR-64-36
Contract 950896

28 October 1964

Prepared for

CALIFORNIA INSTITUTE OF TECHNOLOGY
JET PROPULSION LABORATORY
4800 Oak Grove Drive
Pasadena, California

II

RE-ORDER No. 64-525

CONTENTS

RE-ORDER No. 64-525

IV

RE-ORDER No. 64-525

ILLUSTRATIONS

RE-ORDER No. 64-525

ILLUSTRATIONS (Cont'd)

RE-ORDER No. 64-525

ILLUSTRATIONS (Cont'd)

ILLUSTRATIONS (Cont'd)

RE-ORDER No. 64-525

ILLUSTRATIONS (Concl'd)

E-ORDER No. 64-525

1.0 SUMMARY

Volumes I through V of this report present the results of a four-month parametric analysis and conceptual design study conducted by the Research and Advanced Development Division of Avco Corporation for the Jet Propulsion Laboratory. The study objectives included a parametric analysis of the unmanned flyby bus/lander concept for scientific investigation of Mars during the 1969 and 1971 launch opportunities, a conceptual design of the selected configuration, and a development and cost plan indicating the program leading to development and first flight of the Advanced Mariner vehicle in 1969.

The flyby/lander concept utilizes a 1493-pound spacecraft launched on an Atlas Centaur Launch vehicle. The scientific capability of the lander and flyby bus vehicles were determined to obtain a balance between scientific data and overall systems complexity comensurate with the first landing mission to Mars.

The lander vehicle separates from the flyby bus vehicle prior to planet encounter, enters the planetary atmosphere, and descends to the surface on a parachute. During atmospheric entry, parachute descent, and surface operations, the lander analyzes the Martian atmosphere; and for five hours after impact determines wind velocity as well as performing a simple life detection experiment. The information is transmitted to Earth via both a direct transmission link to the DSIF and is also relayed through the flyby bus which has been placed on a delayed flyby trajectory for this purpose. The flyby bus also collects interplanetary data and maps the planet. The lander vehicle has been designed to accommodate the minimum projected atmosphere for Mars (11 millibar surface pressure) and surface winds gusting to 200 ft/sec resulting in impact loads of up to 1500 g for a landed payload protected by crushable material. The lander is to be dry heat sterilized to avoid contamination of Mars with Earth organisms while the flyby bus is placed on a biased trajectory providing a small probability of entering the planetary atmosphere and therefore is not required to be sterilized.

System Analysis shows a minimum of three launch attempts are necessary to achieve an 84 percent chance of a successful mission in the 1969 and 1971 launch opportunities; this requires that the program begin in early 1965 to meet a 1969 launch date.

The development and cost plans are included in this volume, and are treated herein as essentially two separate documents.

1.1 DEVELOPMENT PLAN

The purpose of the development plan is to identify, organize, and discuss the major efforts required to carry out a program resulting in the successful completion of the 1969 and 1971 Mars lander missions, according to the schedule shown in figure 1, and using the lander and bus concepts presented in volumes III and IV.

RE-ORDER No. 64-525

ADVANCED MARINER
MILESTONE SCHEDULE

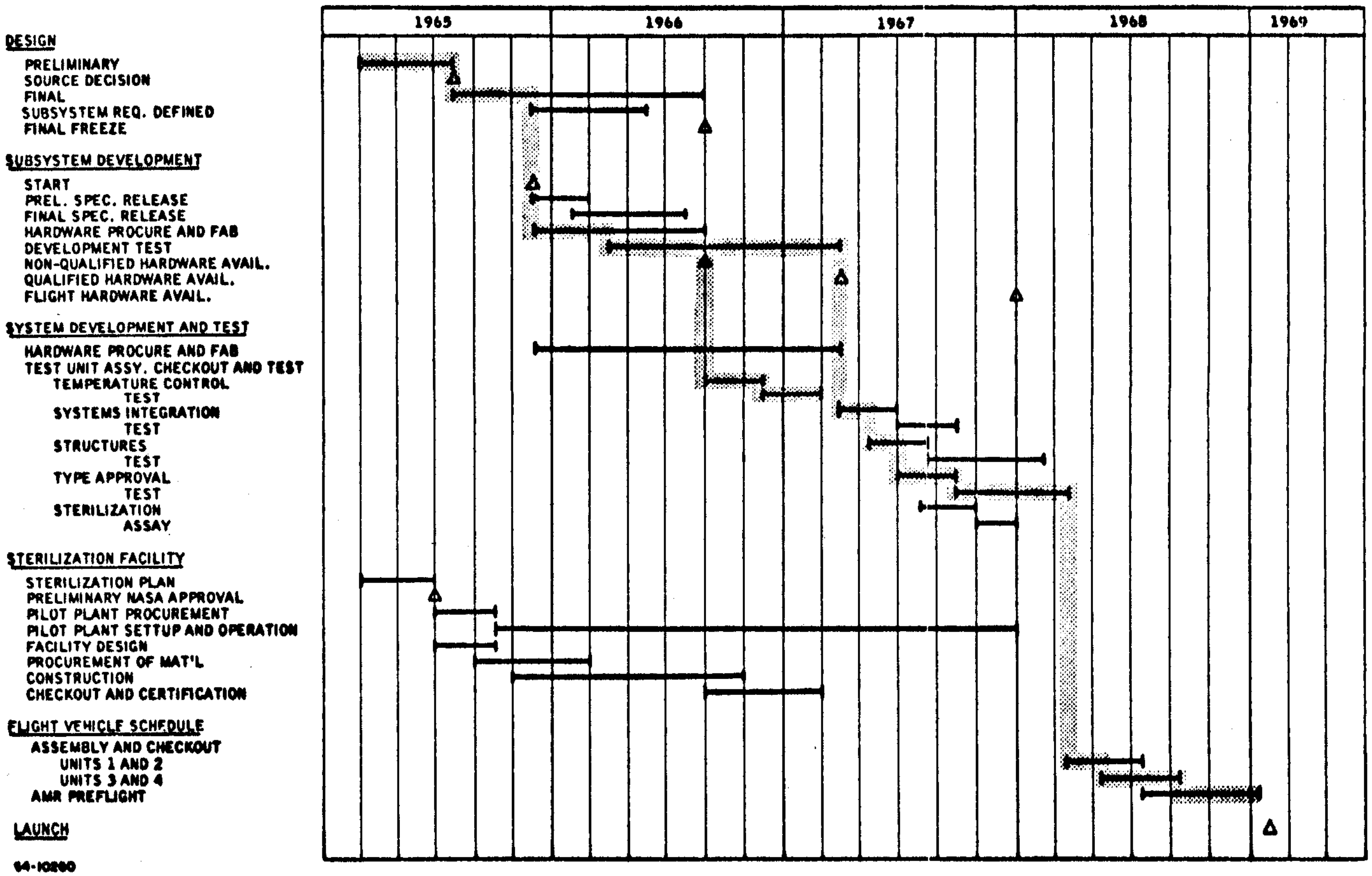


Figure 1 ADVANCED MARINER MILESTONE SCHUDLE

In duration the plan covers from the beginning of the preliminary design in March 1965, through the follow-up activities after the 1971 launch.

During this time period, the plan covers the following major activities:

Preliminary Design
Final System Design
Subsystem Development Programs, including

Subsystem Design
Development Hardware Procurement
Development Testing
Subsystem Qualification Testing

System Hardware Procurement and Fabrication
System Development and Testing
Flight Hardware Procurement and Testing
Sterilization Facility

In its treatment of the above activities, the Development Plan makes use of several ground rules, outlined as follows:

Hardware covered:

Bus, Lander and Bus/Booster Interface Only. No scientific instrumentation, except for Bus TV subsystem.

Number of Units Covered - 1969 Launch.

System Test - Five Vehicles.
Flight - Four Vehicles, (two flight and two spare).

Number of Units Covered - 1971 Launch.

System Test - one Vehicle.
Flight - Four Vehicles (two flight and two spare).

Subsystem development is carried out for the 1969 launch but not for the 1971 launch.

The vehicles used for the 1971 launch are identical copies of those used in the 1969 launch.

The activities of the entire program may be generally identified in two classes: hardware activities and development activities. Hardware activities are those associated with the following:

Fabrication, Quality Control, and Test of Flight Hardware.
Fabrication, Quality Control, and Test of GSE for Flight Hardware.
Acceptance Testing of Flight Hardware.
Spacecraft Field Support Activities.

Development activities are, as a class, all of the other activities of the program. They may, however, be subclassed in three categories:

1. All Fabrication, Quality Control, and Testing activities associated with system test hardware and its GSE.

2. All design, management, and management support activities, such as Project Office, Reliability, Quality Assurance, Systems Analysis, and Documentation.

3. All activities concerned with the conduct of the several subsystem hardware development programs which are required to develop bus and lander subsystems.

The schedule shown in figure 1 above indicates the relationships of the major program activities. It is organized first to assure that the 1969 launch date can be met, and second to maximize the time available for the conduct of subsystem development programs. In view of the fact that no development is scheduled for the 1971 launch, that portion of the schedule is not tight, and is not shown here. It is shown, however, in the schedules section of this volume.

Preliminary design is expected to start on 1 March 1965, being awarded to two prime contractor candidates. The awards are expected to result from a normal RFP-proposal exchange, and it is expected that the activity will last five months and be complete by 1 August 1965. It is expected that JPL will closely monitor the activities of these contractors and perform appropriate analyses throughout the period, so that the decision of contractor choice can be made on 1 August 1965. The winning contractor would then continue into the final design stage.

It is this point in time which actually governs the start of the subsystem development programs, since it is estimated that it will take five months of final system design to produce subsystem requirement specification adequate to initiate subsystem development activities.

The subsystem development programs required are the following:

Bus Subsystem Development Programs:

Television
Payload Platform
Communication and Power
Attitude Control

Propulsion
Temperature Control
Bus/Lander Separation System
Science Liaison (both Bus and Lander)

Lander Subsystem Development Programs:

Aerodynamics
Communication and Power
Structures
Thermodynamics and Material
Parachute
Impact
Propulsion
Temperature Control

For the bus two of the more critical of these is the attitude control program and the separation program. The first is scheduled tightly because the lead times necessary for developing such components as propellant tanks are characteristically long. The second is thought to be critical because of its complexity and the liklihood of delays in addition to the fact that pyrotechnic procurement can be a long lead time item.

A generally critical item for the lander is the requirement that all its components must be heat sterilizable. There is nothing in the conceptual design which is not considered sterilizable, but the severity of the requirement makes likely the possibility of problems in this area.

The subsystem development programs continue until the end of March 1967, and must be complete by that time because of constraining activities later in the program.

Five system test units are planned, the last four of which are to be assembled from qualified subsystems. The minimum fabrication schedule for these four governs when the systems tests can start and of these, the system type approval test is the controlling one, extending through March 1968.

It is reasoned that assembly of the flight hardware and spares should not start until the type approval testing is complete. In this way it is assured that no major retrofits will be required on flight hardware.

Flight vehicles are assembled in pairs, with two backup spares being the second two and also being the governing factor on when assembly of the first two units must start. In order for the spares to be available at Launch time, they need four months at the launch site for checkout and preflight mating and testing. The two-month overlap between assembly activities is considered minimum.

RE-ORDER No. 64-525

The program elements chiefly constraining the subsystem development programs are therefore the following, in reverse order:

Spacecraft flight units need four months at launch site.
Assembly of flight units must start by 1 April 1968.
Type approval testing must be complete by 1 April 1968.
Assembly of test vehicles controls when type approval testing can start.
Development programs must provide qualified hardware for system test unit assembly

In an effort to shorten the AMR preflight activities to a minimum, the planned approach is to carry out the launch site compatibility and integration program using the system type approval unit after those tests are complete. By doing this, when the flight units and spares arrive, they will require only the usual launch site checkout and preflight and booster integration activities, which combined, are estimated to require four months.

In figure 1 above, sterilization is shown as a separate category to emphasize its overall importance to the program and the fact that it is a long lead item.

The underlying constraint in the sterilization schedule is that the clean room and terminal sterilization facilities be available for assembly of the four systems test units which are composed of qualified subsystems. This availability date is 1 April 1967. In order to accomplish this, the indicated schedule has been established, which requires that sterilization planning be carried on along with preliminary design (this means it will have to be done by both competing contractors). At about the same time that the winning contractor is chosen, the plan should be approved so that both pilot plant and facility acquisition efforts can start. The facility schedule indicated is considered the minimum realistic, and the pilot plant activities are carried on through the completion of the sterilization assay.

1.2 COST PLAN

The purpose of the cost plan is to estimate the cost of doing the things called out in the development plan in the manner that they are planned there and at the times indicated in the schedules.

The format for the summary cost plan is indicated in figure 2, which is a presentation of the total costs of both 1969 and 1971 launches. These costs, as well as the others presented in volume V are governed by several ground rules which are indicated in the following list.

THE SINGLE MOST IMPORTANT GROUND RULE FOR COSTING PURPOSES IS THAT NOTHING GOES WRONG. THIS IS NEVER COMPLETELY TRUE, BUT ALLOWS THE READER TO JUDGE THE IMPACT OF TROUBLE BASED ON HIS OWN EXPERIENCE.

RE-ORDER No. 64-525

($ x 10^{-3})

CALENDAR YEAR

	1965	1966	1967	1968	1969	1970	1971	1972	Total
Prel. Design	2,397								2,397
Syst. Anal. & Int.		1,344	1,925	2,093	2,067	1,941	1,290	434	11,044
Final Design	2,607	4,710	3,161	1,081	94	56			11,709
Devel. Prog:									
Bus									
TV		1,380	685						2,065
Payload Plat.		405	53	39	10				507
Comm. & Pwr		2,787	437						3,224
Attitude Cont.		1,122	1,320						2,442
Propulsion		2,240	1,600						3,840
Temp. Cont.		330	350	117					797
B/L Sep. Syst.		1,550	580						2,130
Science Liaison		17	17	17					51
Lander:									
Aerodynamics		892							892
Comm. & Pwr		2,663	333						2,996
Structures		548	430						978
Thermo & Mat'l		1,116	420	33	3	3			1,575
Parachute		1,990							1,990
Impact		1,833							1,833
Propulsion		421	421						842
Temp. Cont.		245	155	99					499
Sterilization	2,700	1,800	1,800						6,300
Science Liaison		27	27	26					80
Mfr & Q. C.		11,572	23,404	9,669	16,144	7,092	1,035	68	68,984
GSE		4,956	2,362	1,063	411	108	30		8,930
Syst. Testing:									
Temp. Cont.		236	472	94					802
Syst. Integ.			280	2,255					2,535
Structural			494						494
Type Approval		26	764	112					902
Steril. Assay			429			429			858
Accept. Testing			820	820		820			2,460
Rel. & QA		1,950	2,028	926	344	140	96		5,520
Documentation		192	268	265	108	108	137		1,078
Prog. Mgmt.		146	198	194	188	93	32		851
TOTAL	7,704	46,498	45,233	19,939	19,369	10,790	2,570	502	151,605

Figure 2 1969 & 1971 LAUNCH COSTS - TOTAL PROGRAM

RE-ORDER No. 64-525

Hardware Covered:

Bus, Lander, and Bus/Booster Interface Only.

Number of Units Covered - 1969 Launch.

System Test - Five Vehicles.
Flight - Four Vehicles, (two flight and two spare).

Number of Units Covered - 1971 Launch

System Test - One Vehicle.
Flight - Four Vehicles (two flight and two spare).

Subsystem Development is carried out for the 1969 launch but not for the 1971 launch.

Vehicles used in 1971 are, for costing purposes, identical copies of those used in 1969.

Hardware costs are those associated with

The Fabrication and Quality Control of Four Flight Units.
Fabrication and Quality Control of Flight Hardware GSE.
Acceptance Tests of Flight Hardware.
Spacecraft Field Support.

Development costs are all the other program costs and can be classed in three ways:

Costs associated with the five system test units.
Support cost such as

Management
Reliability
Quality Assurance
Documentation

Subsystem development costs.

The dollar figures shown are total dollars, defined as including the following:

Direct labor
Labor overhead
Materials
Materials handling

Travel
Consultants
Computer time
General Administration

A few comments relative to figure 2 can be made here. A more detailed discussion will be found in Section 3. 2.

The most expensive single year is 1966, since most of the development activities occur then.

While the 1965 costs may seem high in terms of budgetary considerations, it is noteworthy that most of the costs occur after the start of fiscal year 1966. The only costs occurring earlier are the preliminary design and sterilization planning of the two competing contractors.

Most of the manufacturing costs are incurred in 1967 and 1968; for that reason they are the second two most expensive years.

Table 1 below is a summary of the total costs indicated in the cost plan. There is a significant reduction in the 1971 costs, primarily because of the ground rule not to carry on subsystem development for that opportunity. It is also noteworthy that bus hardware costs are about double per unit those of the lander. This is principally because of the greater payload complexity of the bus, including the solar panels. The hardware cost decreases slightly in 1971, since the GSE can be used again after refurbishment. Bus development costs are actually about the same as the lander, but appear higher in this summary because of the cost of five sets of system test hardware, which are more expensive for the bus.

The format for the detailed cost plan is shown in figure 3. One such page is used to break down the costs of each line item indicated in figure 2.

This breakdown is largely self explanatory, and for more details the reader is invited to examine section 3. 3, in which each cost area is discussed.

The same ground rules apply to these costs as apply to the summary costs above.

GE-ORDER No. 64-525

TABLE 1

PROGRAM COST SUMMARY
(Thousands of Dollars)

	Launch Window 1969	1971	Total
Bus			
Development	$ 53,116	$ 5,549	$ 58,665
Hardware	17,007	16,163	33,170
Subtotal	70,123	21,712	91,835
Lander			
Development	41,093	3,455	44,548
Hardware	8,216	7,006	15,222
Subtotal	49,309	10,461	59,770
Grand Total	$119,432	$32,173	$151,605

RE-ORDER No. 64-525

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development									
Hardware									
Total									
In-House Subtotal									
Outside Subtotal									
1971 Launch									
Development									
Hardware									
Total									
In-House Subtotal									
Outside Subtotal									
LANDER:									
1969 Launch									
Development									
Hardware									
Total									
In-House Subtotal									
Outside Subtotal									
1971 Launch									
Development									
Hardware									
Total									
In-House Subtotal									
Outside Subtotal									

Figure 3 DETAIL COST FORMAT

RE-ORDER No. 64-525

2.0 DEVELOPMENT PLAN

2.1 INTRODUCTION

The development plan and cost plan are presented separately in this volume. The introduction to the cost plan is contained at the beginning of that section, though mentioned here briefly.

The development plan contains seven principle sections, described as follows:

1. Program Management

This section contains discussion of direct management responsibilities, which are both technical and financial in nature, and indirect responsibilities, which are concerned with supervision of certain specialized activities, such as reliability and quality assurance efforts.

2. Design and Design Control

This section contains discussions of the basic design efforts, preliminary and final, and the three major activities which act as design controls: systems analysis, reliability, and quality assurance.

3. Sterilization

This section contains a detailed discussion of the sterilization aspects of the program, including requirements, facilities, training, and monitoring.

4. Subsystem Development

This section contains first a make-or-buy discussion followed by discussions of the subsystem development programs required for this program. These programs involve both prime contractor and subcontractor efforts. In support of the subsystem development programs, discussions are included on ground support equipment, and problem areas.

5. System Development

This section contains discussions of the basic manufacturing plan and quality control efforts, following which each of the systems tests is discussed. The system tests with one exception are conducted on complete spacecraft assembled from qualified subsystems. The final part of this section is a discussion of system problem areas.

6. Flight Hardware

This section contains discussions of the system assembly process and the checkout and prelaunch activities required prior to launch.

RE-ORDER No. 64-525

7. Schedules

This section contains all the schedules presented in the development plan: first, a summary schedule and then a detailed schedule for each significant activity of the program, including one for each separate subsystem development program.

8. Facilities

This section presents briefly a list of the more unusual facilities which are expected to be required for this program. These do not necessarily have to be procured for the program but must be made available on some basis.

The cost plan is presented second in the volume and is based on the development plan. Aside from the introduction it contains two sections: summary and detail.

1. Summary Section

This section presents annual costs for each of several activities comprising the program. The presentations are by launch window, bus and lander, and development and hardware, including the permutation of combinations.

2. Detail Section

This section presents a detailed expression of the annual costs of each activity summarized in the summary section. These are presented in the following terms: by launch window, bus and lander, and expected prime contractor and subcontractor costs.

2.2 PROGRAM MANAGEMENT

Management of this program will require both direct and indirect action on the part of the Project Manager and his Project Engineers.

Direct action responsibilities are both technical and financial in nature and include the following:

1. Technical

   Program Planning
   Design Development
   Configuration Control
   Schedule Coordination
   Coordination with Vendors and Subcontractors
   Coordination with the Customer
   Response to New Directives
   Documentation

2. Financial

Line Function Activity Control
Financial Reporting
Generation of Cost Estimates
Maintenance of Schedules

Indirect responsibilities are those concerned with monitoring other types of activities during the program. These include:

Systems Analysis
Reliability
Quality Assurance
Manufacturing Control
Quality Control
Subsystems and Systems Testing
Spacecraft Field Support
Make-or-Buy Committee
Other Administrative Services

With the exception of the last item, the activities listed above are all discussed elsewhere in this plan and therefore need no discussion here, other than to point out that they are all highly specialized tasks, and therefore require the monitoring of general program management to assure that the activities are kept under control and administered efficiently.

Other administrative services include contracts, budgets, reproduction services, and so forth, and it is the responsibility of program management to see that these services are used effectively in support of the program.

2.2.1 Direct Management Responsibilities -- Technical

Program planning involves amplifying and detailing all the basic program activities beyond the stage of this development plan, so that the resulting program plan is a working tool, identifying not only what is to be done, but who will do it, where, by when, and so forth. The program plan will have to be kept up to date as changes occur and analyses continually made to assure that the program will be successfully completed on time.

Design development responsibility for the designs of both the bus and lander should be assigned to separate project engineers who will be responsible for coordination of all the subsystem design activities, assuring that the overall system design is compatible with them and that it still meets the system requirements imposed by the contractual work statement.

Configuration control. Whenever design changes occur, they must be properly incorporated into the design, but action must be taken to assure that the change does not violate configuration constraints. In the event that a proposed change would do this, it must be revised so that the reason for the change is still satisfied, but the configuration still meets specifications.

Schedule coordination. As changes occur in the schedules of specific program elements, it is a management responsibility to coordinate the changes with other schedules so that all schedule interfaces remain satisfactory.

Coordination with vendors and subcontractors. Throughout the program vendor and subcontractor coordination must be carried on in the areas of design, fabrication, testing, and delivery schedule for the purpose of continually assuring that specifications and schedules are being met.

Coordination with JPL. Throughout the program coordination with JPL will be required to stay informed on changes as they may occur and to keep JPL informed of program progress.

Response to new directives. During a program of this size it is to be expected that technical directives will occur and management is responsible to see that these are properly understood and carried out.

Documentation. While program management does not actually write much of the program documentation, this being done mostly by engineers directly concerned with the reported function, it is responsible for what is reported, and is therefore ultimately responsible for this task. The documentation necessary to record program progress and to help direct and control program effort can be defined as belonging in two broad categories: program control documentation and NASA contractually-required documentation, a category which includes both project-peculiar documentation and standard "software" documentation. These categories are briefly discussed below.

Program control documentation is intended primarily for internal working purposes. It should serve primarily as a tool to provide internal technical program information. It should record the plans under which the contractor is carrying out its tasks, the historical evolution of the work accomplished against these plans, and the current status of the program. It should define the project organization and assign responsibilities, include instructions and data relative to schedules, fiscal, communication and other controls, establish the pattern for project review, and maintain the status of the action items resulting from these reviews; it should include appendixes which present basic project information, such as the work statement, status of facilities, classification instructions, etc. The documentation system should be IIS oriented. This documentation should be updatable as required in order to minimize delays in the transmission of program technical information. At the conclusion of the program much of this documentation can be useful as material for the final technical report.

The category, project-peculiar documentation should include plans, directives, procedures, schedules, status reports, technical reports, and other project-related documentation. The category "software" documentation should include drawings, test specifications, failure reports, change orders, inspection reports, and other hardware associated documentation.

2.2.2 Direct Management Responsibilities -- Financial

Line function activity control. During any program that involves considerable efforts of line departments or other supporting functions, where people may not be working full time on the program, care must be exercised to assure that the efforts being expended in the name of the program are in fact being efficiently applied and that the most effective levels of manpower are being used.

Financial Reporting. Two types of financial reporting must be carried on: formal reporting to JPL and internal reporting. Formal reporting should be done monthly and be contract-oriented, while internal reporting should be weekly and be task-oriented.

Generation of cost estimates. Estimates are usually required for determining cost to completion and for response to technical directives, where they represent an increase in contract scope.

Maintenance of schedules. While schedule coordination is essentially a technical responsibility from the standpoint of performance, the maintenance on a regular basis is usually the responsibility of financial management because of their close tie-in to costs and cost estimating.

2.3 DESIGN AND DESIGN CONTROL

2.3.1 Introduction

While design activities are often thought of as being basically independent of certain other activities, although influenced to a certain extent by them, the approach here has been to combine into one section both the principal design activities and the activities which exert the greatest influences on them. For this reason, systems analysis, reliability and quality assurance discussions are contained here along with final design.

System analysis efforts act principally to control the design so that it maximizes mission return, and is not overemphasized in particular areas.

Reliability efforts control design by assuring that it will meet reliability goals. This may mean requiring certain types of approaches, or redundancies which may otherwise be overlooked.

Quality assurance efforts are directed to design in that the quality of product necessary to achieve reliability is designed into it. This includes not only in-house design and specification control, but also vendor and subcontractor control in the same areas.

2.3.2 Preliminary Design

The preliminary design activity of the program is expected to involve two competing prime contractor candidates and run from 1 March 1965, through 31 July 1965, a period of five months. Contract awards to these contractors is expected to result from a normal RFP-proposal exchange with JPL, which would occupy the time between the completion of the present study and 1 March 1965. These time spans are indicated on the summary schedule in figure 1 of the summary and figure 8 of the schedules section.

The concept of the preliminary design activity is that it be done in a manner such that final design can immediately follow, being done only by the winning contractor candidate. Operating in this manner makes it possible to start the required subsystem development program earlier than would be possible if a delay occurred between these two activities. It is therefore required that JPL be able to make the contractor choice decision at the end of the five-month preliminary design period. To be able to do this, it will be necessary for JPL to assign a design analysis team to each of the contractors to monitor their work, making appropriate analyses as it is carried on. The two teams and JPL management would then have acquired enough background analytical material to be able to make their decision at the end of the preliminary design contracts, giving a letter of intent immediately to the winner, so that he might carry on without delay.

The products of the preliminary design efforts would by definition be what was called for in the RFP work statement. Specifically, however, it would be expected that the following would be accomplished:

Preliminary Configuration, System and Subsystem Layouts.
Preliminary Subsystem Performance Requirements.
Preliminary Subsystem Specification Requirements.
Systems Analysis of Mission Performance, Based on Proposed Design.
Detailed Development Plan.

2.3.3 Final Design

2.3.3.1 Flyby/Bus

Upon completion of the preliminary design study, systems specifications will be prepared for the vendors, subcontractors, and internal engineering groups. These specifications will provide the user with the required performance, environmental design criteria, and weight and dimensional constraints.

A structural design of the flyby/bus will be started and concurrent with preparation of the structural design, a mockup of the flyby/bus based on the preliminary design will begin. The purpose of the mockup will be to help insure compatibility of the systems with the structural design Specifically, the mockup will guide the placement and positioning of the black boxes within the six compartments provided and tankage within the cylindrical shell. During this phase it will be important to consider both location of equipment from the view point of satisfying both thermal balance and center of gravity balance of the flyby/bus. Optical and electromagnetic sensors such as the TV camera and antennas must be mounted so as to have a clear field of view, based on the look angle requirements over the mission. The mockup will be used to establish the wiring harness layout and determine leads shielding requirements to prevent electrical interference. Also clearance for and location of plumbing for the propulsion system, the cruise mode attitude control, and thrust vector control system will be provided. Separation clearance of the spacecraft from the booster and lander from the flyby/bus will also be observed.

The design areas will serve as a clearing house to process all design modifications and to determine their influence on the spacecraft. Final design layouts will be generated for vehicle fabrication. Specific tests will be conducted on development hardware units to determine the transmissibility of the structure and the resultant dynamic loads on the equipment mounted to the structure. Structural design will be modified so as to determine and decrease the amplification factor.

Tests will be conducted to check out the structure with static equivalent loads, and tests will be designed to check out the explosively actuated separation system, gimballed payload platform, and deployable solar panel.

The types of tests required during the design development of the flyby/bus include the following:

1) Structural test - both static and dynamic.

2) Spacecraft-booster separation system.

3) Mechanical actuation devices.

4) Explosively actuated covers and latches.

Structural test for the flyby/bus will include simulation of static and dynamic loads during four modes of spacecraft operation. These include:

1) Spacecraft launch configuration - lander on top of the flyby/bus; gimballed playload platform locked; deployable solar panels latched.

2) Cruise mode with lander; gimballed payload platform latched; solar panels extended and locked.

3) Thrusting mode with lander; gimballed payload platform latched; solar panels extended and locked.

4) Cruise mode without lander; solar panel extended and locked.

   a) Gimballed payload platform latched.

   b) Gimballed payload platform in tracking mode.

A critical study will determine which of the above modes govern the structural design with the possible elimination of some .

A one g resonant search of a development hardware unit will be conducted for the spacecraft in the four modes of operation. This search will enable the natural frequencies and transmissibility of dynamic loads to the components to be identified. The spacecraft will then be structurally detuned so that the dynamic structural loads do not exceed the design criteria envelope. Transmissibilities will be determined to provide the design information necessary to detune bracketry and other structural elements to acceptable transmissibility levels, thus assuring that the final design will not be likely to give rise to these types of problem.

Spacecraft-booster separation will cover the development of a flexible linear shaped charge circumferential severing system. This system will separate the flyby/bus from the booster near the upper end of the adapter section. Development testing of mechanical actuation devices will cover the mechanical positioning and deployment of the solar panels and gimballed payload platform. Also explosively actuated covers and latches that release the solar panels, and gimballed payload platform will be developed and tested.

2.3.3.2 Lander

In the initial phase of the lander development certain mechanical-functional subsystem must be performed for all environmental conditions imposed on the subsystem to ensure compatibility with other subsystems and foremost to assure high reliability of operation of the particular subsystem. These tests will be conducted on several candidate subsystems in an effort to assure an accurate tradeoff on that subsystem. All tests will be performed prior to design freeze in that they will influence the final system selection.

Design layouts shall be generated in order that functional subsystems can be evaluated for compatibility with related subsystems and to indicate interface problems with emphasis on size and weight control. Results of all subsystems and system tests along with full scale model arrangement evaluations will be incorporated in design development layouts and functional testing.

Finally, all subsystems will undergo verification tests to prove that design requirements are satisfied and that high probability of success is possible. All final design layouts will be based on results of the previous development tests and design tradeoffs. However, these layouts will be modified during the verification test program (which follows the design freeze) in the advent that design changes are indicated.

The following are some of the more pertinent subsystem functional tests that are anticipated for the development of an Advanced Mariner lander.

1) <u>Drogue chute deployment</u>

Explosive systems associated with the deployment sequence shall be evaluated in terms of initiation and time delays. Actuation of the cover assembly and riser line cover to attachments will be tested under the design environment.

2) Afterbody jettisoning

Explosive systems associated with this function system shall be evaluated by a series of element tests on simulated hardware to determine size and initiation of the explosive circuit. Final full scale subsystems tests will be conducted to measure cleanness of release and time functions.

3) Forebody release

In connection with the main chute deployment operation the forebody release system will be tested. These tests will incorporate scale models for development of system release and simulated models of actual hardware for explosive systems. Required cleanness of operations and sizing will be established for final design.

4) Main chute release

Aside from the main chute deployment development (covered under separate section), system tests will be conducted simulating the release of the main chute at landed package impact on the surface of Mars. Release initiation will be tested and sized with emphasis on the time delay and cleanness of chute jettisoning.

5) Scientific instrumentation deployment

In addition to the impact attenuator jettison development testing (covered under separate section) all deployment systems, after impact, must be tested to determine function operation and to verify design. Such operations as the scientific instrumentation deployment (sticky string and anemometer) must be evaluated through tests to determine clearness and accuracy of deployment sequence. Final sizing of required explosive system will be obtained.

6) Miscellaneous

Several other functional tests will be conducted on all operational subsystems involved with the lander operational sequence (see Lander volume III section 3.3). Among these are included, descent payload jettisoning, antenna erection and pressure venting control.

7) Thermal compatibility

In addition to the above functional test programs other development tests will be required to substantiate thermal compatibility of functional subsystem interfaces (these are in addition to the structural compatibility tests, covered separately). These tests will be in support of the final system tests conducted on an actual hardware assembly and will be conducted on more of a subsystem element test program.

2.3.4 Systems Analysis and Control

The discrete nature of the bus and lander vehicles, yet their complete interdependence on one another for a successful mission, augments the necessity of an effective systems analysis and control activity for the overall technical control of the Advanced Mariner program. Typical areas of responsibility to accomplish this task should include, but not necessarily be limited to, the following:

1. Trajectory analysis to select the near optimum tradeoff for spacecraft system design operations.

2. Detailed determination and control of flight sequence and command.

3. Establish mission data requirements.

4. Synthesis of basic spacecraft design requirements for purposes of detailed hardware study and design.

5. Overall system specification preparation and control activities, including detailed subsystem specification monitoring for proper interpretation of the overall requirements.

6. Control and assignment of all program specifications, e.g., process, assembly, handling, shipping, sterilization, etc.

7. Mission planning and coordination.

8. Configuration and subsystem interface control support.

9. Design coordination.

10. Systems test planning and coordination.

11. Flight vehicle test planning and coordination.

12. Coordination with assembly and test operations for purposes of training and control.

13. Booster vehicle integration control.

14. Booster/spacecraft design interface and test coordination.

RE-ORDER No. 64-525

15. Provide spacecraft-oriented command operations liaison and control.

16. Postflight operations and control.

17. Flight information and postflight documentation.

18. Provide launch site logistics, spare parts, and ground support equipment operations.

One of the more significant systems responsibilities is the preparation of a factory-to-launch sequence, a plan of handling and test activities which are required, and which must therefore be considered in the design.

Figure 4 shows a general hardware flow plan from initial assembly to the spacecraft subsystems through typical significant operation to launch. It is intended that clean room facilities or protective packaging will be utilized, where required from the original manufacture of certain parts through their assembly into subsystems, throughout certain test operations and operations at the launch site. Clean room assembly techniques are required for the lander to assure sterilization by minimizing biological burden before the therminal heat sterilization.

The plan presented assumes a majority of the spacecraft subsystems are prepackaged and are adaptable to automatic checkout procedures to minimize all the checkout tests, but most important, to minimize the launch pad handling and operations.

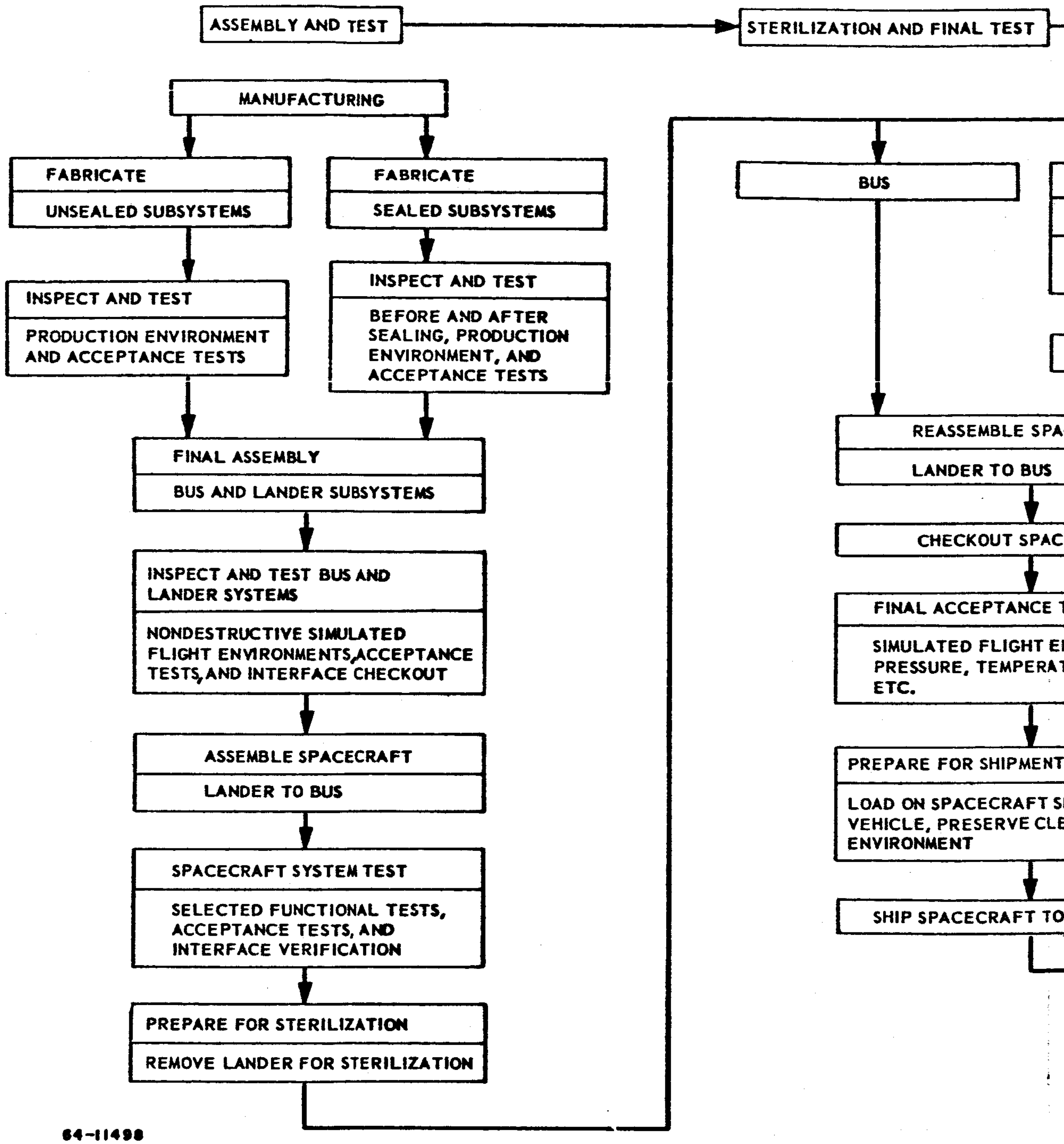
2.3.5 Reliability

The reliability effort concerns itself with monitoring reliability-affecting elements of the program from design through launch, analyses of the impacts of these elements, and the exercise of control over them to the extent that reliability can be maintained or improved within other program constraints. The applicable program elements are indicated on the reliability program plan shown in figure 5. They are discussed below.

a. Program Planning

A reliability program plan should be compatible with applicable provisions of the NASA Reliability Publication, NPC 250-1, "Reliability Program Provisions for Space Systems Contractors." The tasks of the reliability program must be time-phased to synchronize with other activities and events of the master schedule for the overall program. The critical reliability tasks are program reviews, indoctrination and training, subcontractor and supplier control, reliability engineering, design reviews, failure reporting and corrective action, testing and reliability assessment, and program documentation.

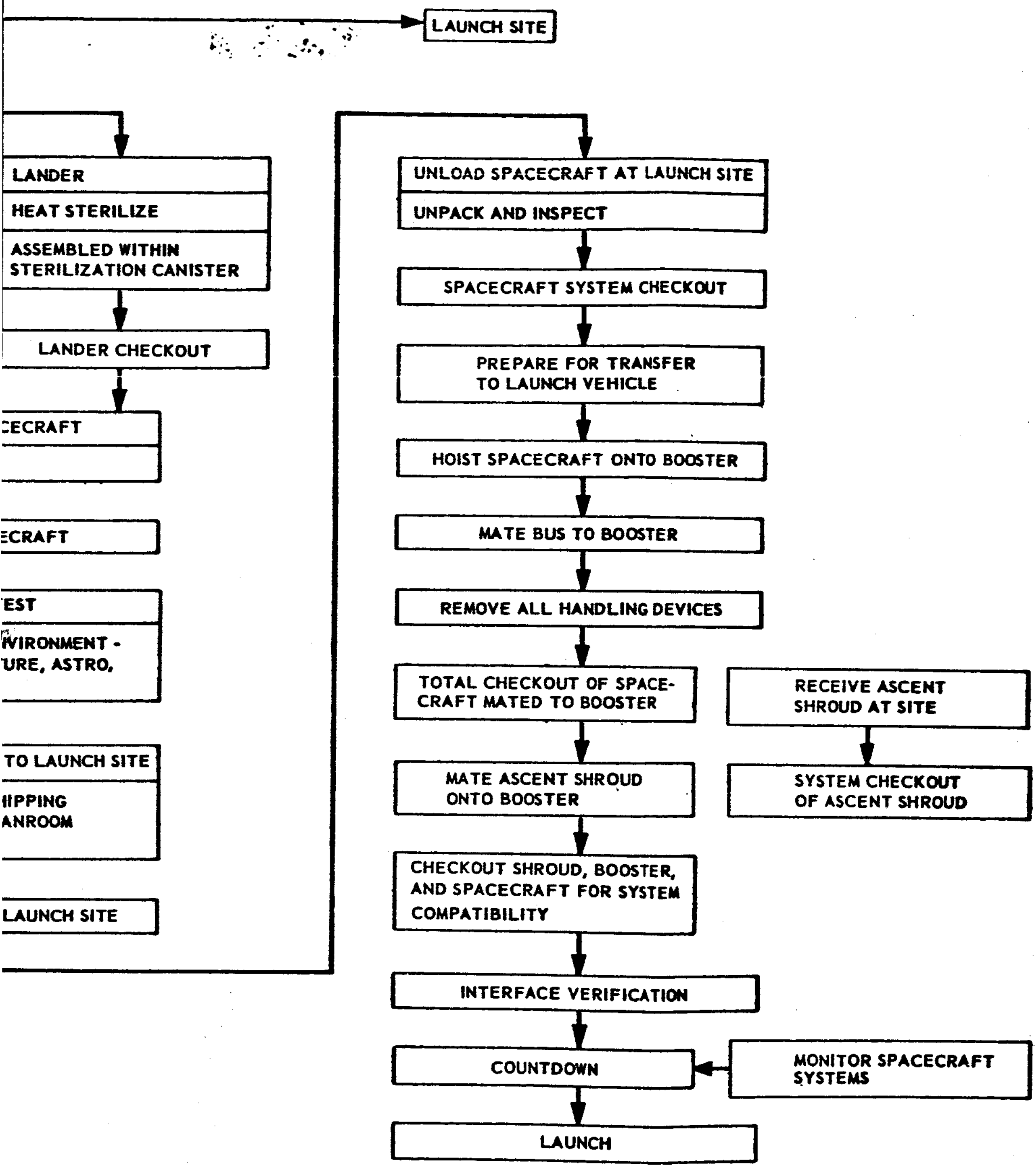
RE-ORDER No. 64-525



64-11498

Figure 4 FACTOR - TO-L

/#



AUNCH SEQUENCE

2#

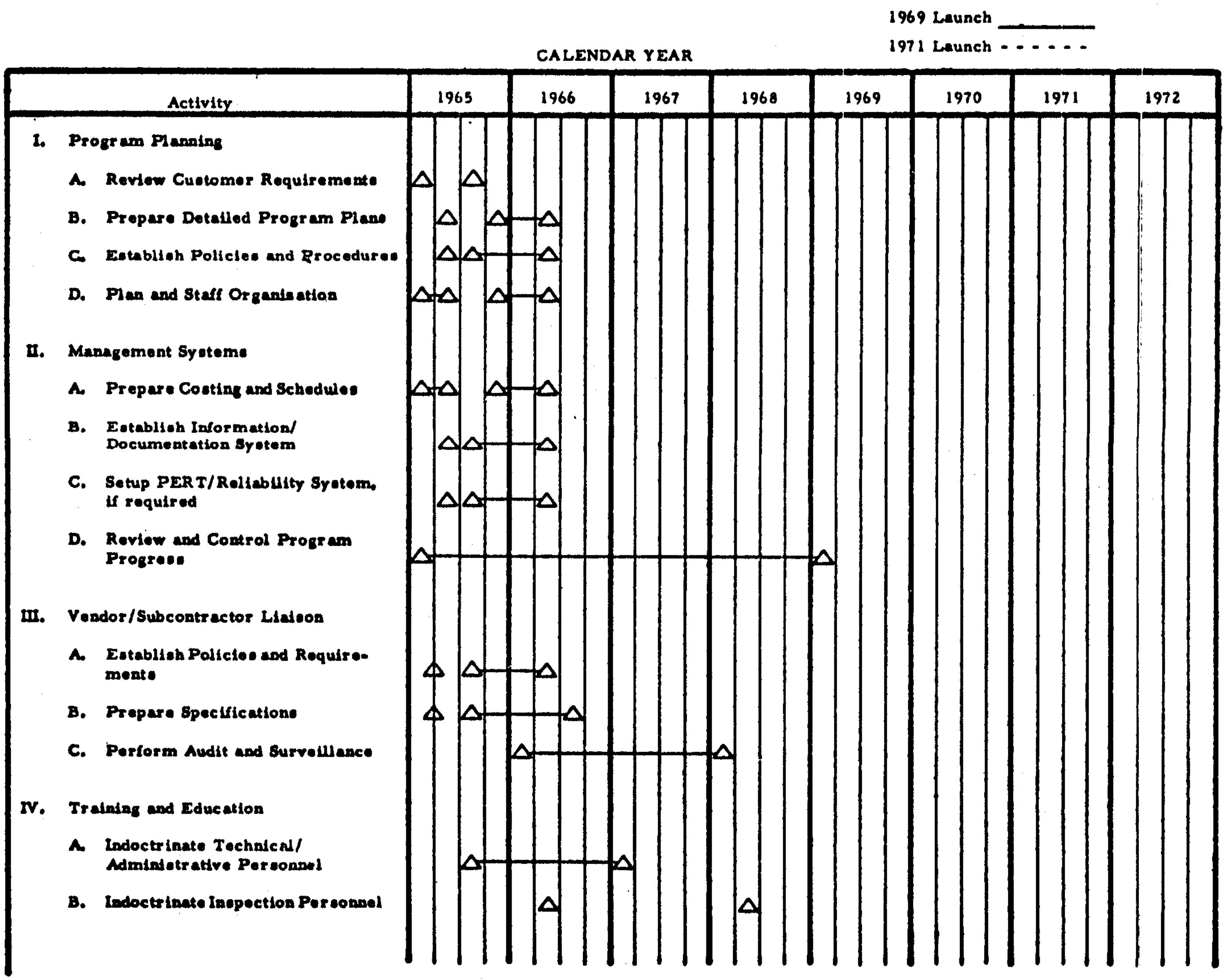


Figure 5 A PRACTICAL RELIABILITY PROGRAM PLAN

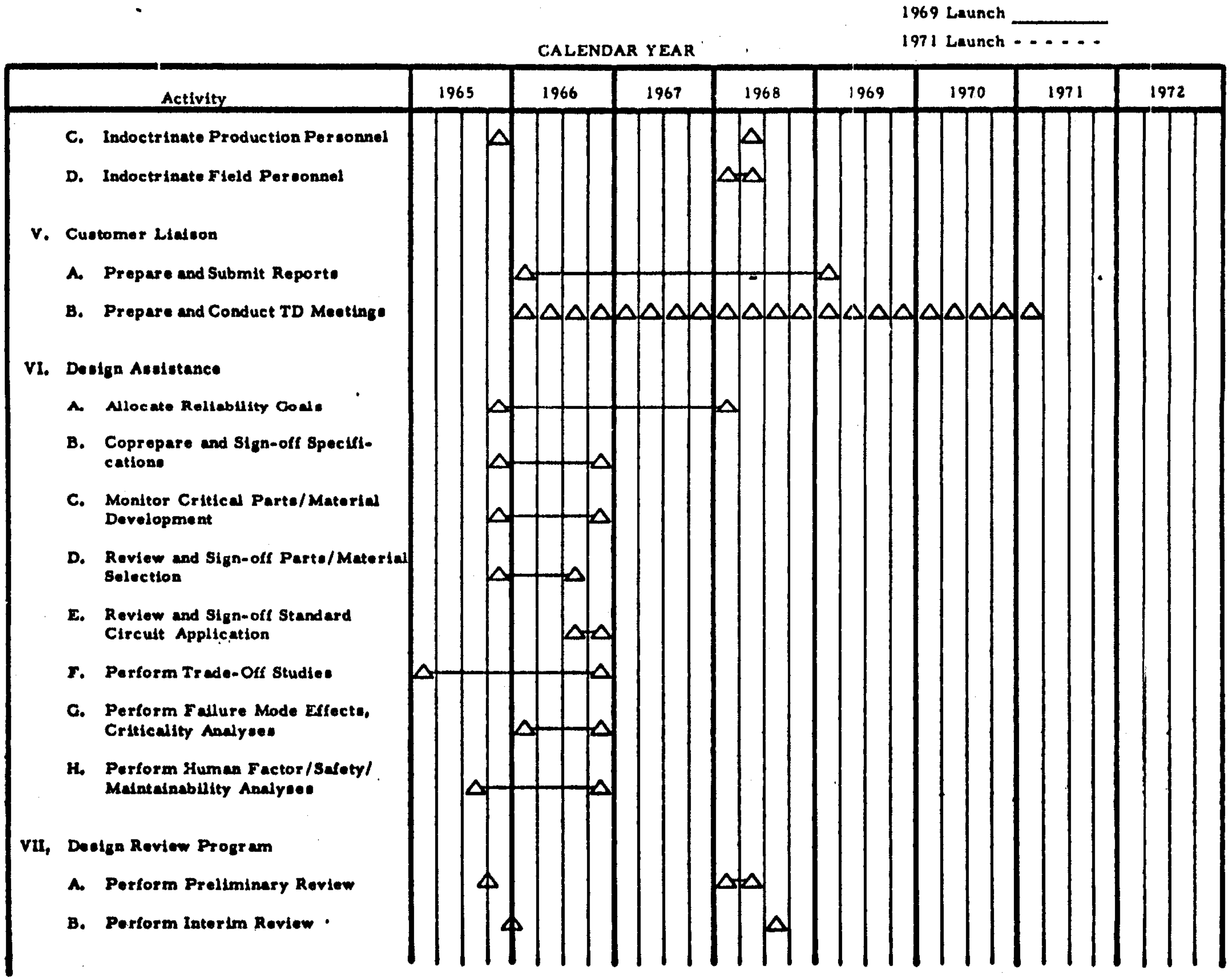


Figure 5 (CONT'D)

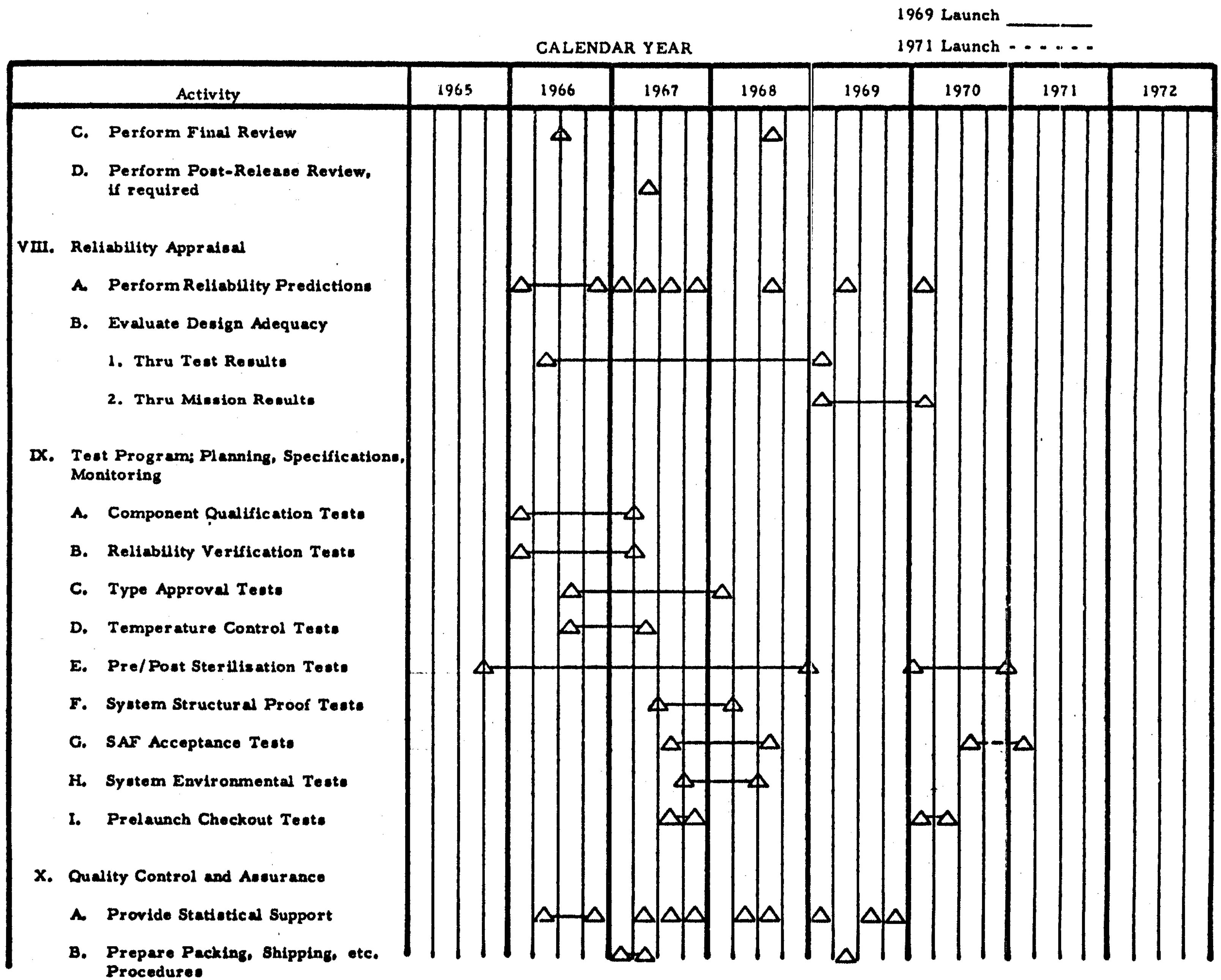


Figure 5 (CONT'D)

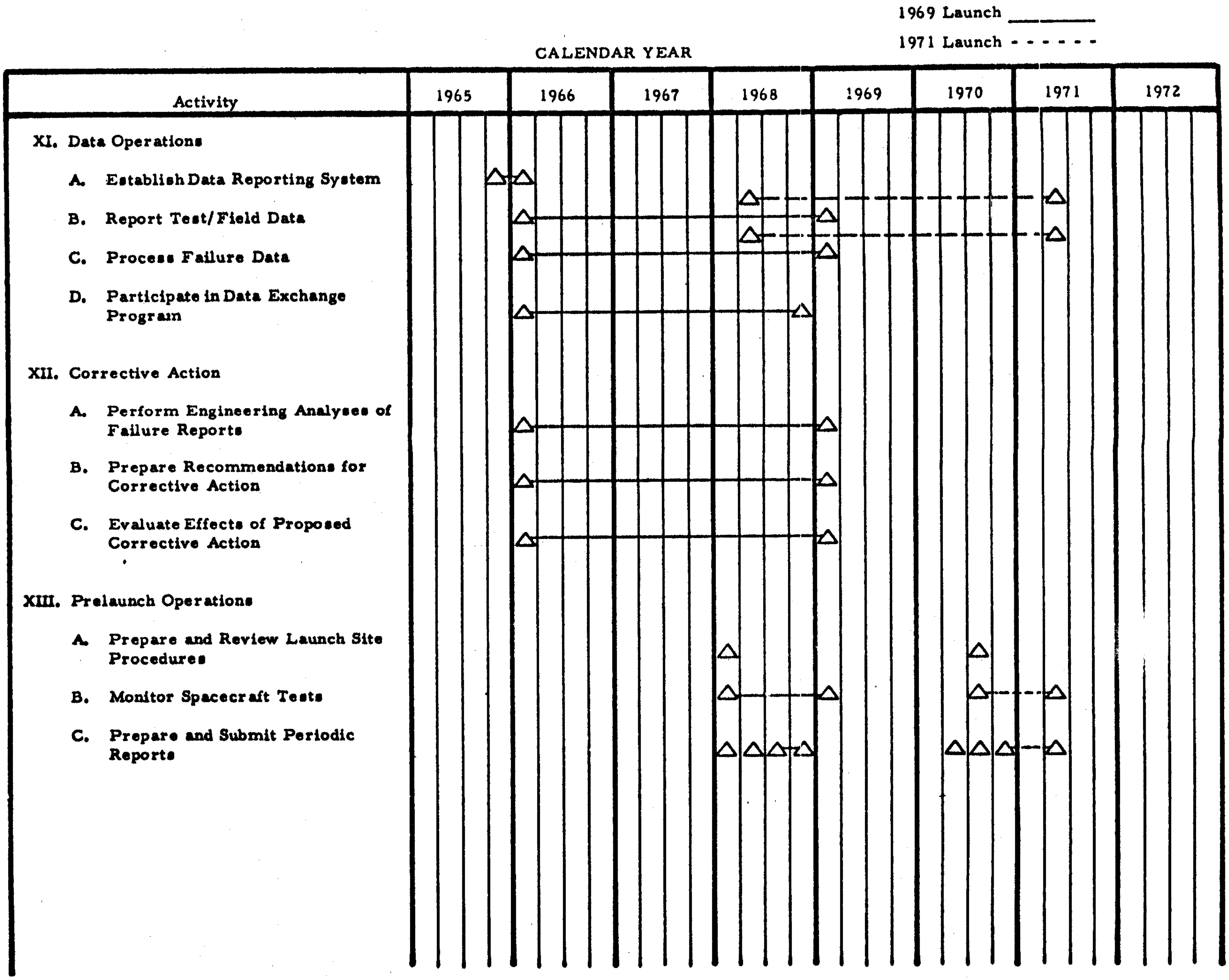


Figure 5 (CONCL'D)

RE-ORDER No. 64-525

b. Program Reviews

Reliability program reviews, usually conducted jointly by NASA/JPL and the contractor, will be scheduled at certain points in the Advanced Mariner program for the purpose of assuring that the reliability agency is as completely informed as possible. To support these reviews, an operating system should stimulate standardization and timely information reporting and provide a single point of access to reliability information.

c. Indoctrination and Training

The training programs for the Advanced Mariner program should aim at stimulating general reliability awareness and cognizance in reliability associated aspects of the spacecraft. It should include management, administrative, production, and technical (both in house and field) personnel. The central theme of reliability training should be motivation toward high spacecraft reliability and its importance to the success of the over-all Advanced Mariner program.

d. Subcontractors and Supplier Control

Because of the severe environment and mission duration and because of the high spacecraft reliability requirements, control of components and hardware procured from subcontractors and suppliers is a particularly important reliability assurance consideration. To achieve the standards needed, specifications delineating minimum reliability requirements must be imposed on all Advanced Mariner spacecraft subcontractor and suppliers. The quantitative reliability requirements on components will be allocated from the reliability requirements of the overall spacecraft.

e. Reliability Engineering

All design specifications should be reviewed by reliability engineers. They should be examined to ensure that reliability requirements and other factors related to the spacecraft design adequacy are properly defined and duly considered. Revisions to these specifications can be recommended as necessary. Reliability goals would then be allocated to the spacecraft systems and components and be stated on the design specifications as numerical reliability requirements.

To help ensure that an inherently reliable spacecraft is designed, the reliability organization should assist the design engineers. In the early stage of the design, parts lists will be made available to designers to assure that preferred, highly reliable components are selected when possible. The JPL preferred parts list, Specification No. ZPP-2061-PPL-D, should be used where possible. Due to heat sterilization consideration all lander parts and material should be examined for favorable high-temperature characteristics. In the absence of supporting evidence to substantiate the reliability of these and other parts, qualification tests are recommended. Similar methods should be used on electronic circuits to assure the selection proven, reliable circuits.

The reliability of the spacecraft should be predicted as initial design data becomes available. As the design becomes more detailed and/or other meaningful data are received, the prediction should be updated accordingly. These predicted values are compared to the allocated reliability goals to indicate potential reliability problem areas. These reliability predictions are also used in planning for test programs and design tradeoff studies. In addition, failure mode, effects, and criticality analysis can be performed to anticipate the significance of potential failures and their resulting effect on spacecraft performance.

f. Design Reviews

The principal goals of formal design reviews are as follows:

1. Preliminary reviews - to consider the basic concepts and techniques, and their compatibility to be employed in the spacecraft design;

2. Interim reviews - to promote design standardization, and to examine function and environmental aspects of the design;

3. Final reviews - to conduct a critical analysis of maintainability features and the hardware interfaces; and to anticipate and resolve source of reliability degradation in production.

Reliability design reviews should be carried out to evaluate the design. These reviews can provide a formal means of recognizing deficiencies in the spacecraft design and initiating design modifications. Design changes in turn should also be reviewed, analyzed, and approved by the reliability agency. These reviews can make use of previously described reliability predictions, failure mode, effects, and criticality analyses, testing, reliability allocations, and other engineering analyses. Part of the design review effort should be a parts and material program to govern the selection, specification, qualification, and application of parts and materials to be used in the spacecraft. The program should be conducted by parts and materials specialists, whose responsibilities should be to (1) assure the selection and qualification of parts which can be sterilized, when necessary, (2) review parts and materials specifications to ensure that all mission and premission requirements are thoroughly considered, and (3) approve parts and materials lists for use by designers of the Advanced Mariner spacecraft. An applications review will ascertain that each part and materials in the spacecraft design is compatible with the requirements of the environment.

g. Failure Reporting and Corrective Actions

Effective corrective action is necessary to assure the inherently high reliability of the spacecraft design. Corrective action requests should be initiated on the basis of (1) failure/malfunction data reported during tests conducted throughout the program and (2) deficiencies recognized during design reviews and engineering analyses. These inadequacies should be examined comprehensively, including a review of failure reports, analysis of failed parts, determination of porblem area severity (criticality, persistence, and duration), and recommended solutions.

h. Testing and Reliability Assessment

The reliability organization should participate in the planning, specification review, and monitoring of all tests. The tests should be planned so that usable data are obtained for evaluating and verifying the degree of conformance to spacecraft reliability requirements at system or lower levels. Test monitoring should ensure that burn-in/debugging tests have been performed so that the spacecraft will not experience infant mortality failures during the prelaunch, checkout, and operational mission phases. Data collected from test may be used to confirm the reliability predictions and to substantiate failure mode and criticality analyses conducted earlier in the program. These test results should assure that pre-established reliability goals are being fulfilled in the Advanced Mariner program.

Reliability and quality assurance controls should be imposed at the launch site. Handling, installation, and checkout procedures should be carefully approved and monitored in the field. Any deviation from established procedure will thus be prevented.

i. Program Documentation

The reliability effort should be sufficiently documented to provide a comprehensive review of program progress. Sufficient documentation to satisfy this criterion has been accounted for in this plan and is discussed above in program management.

2.3.6 Quality Assurance

Assurance and control of quality consists of systematic planning, testing, inspection, and audit activities, the purpose of which is to provide confidence that the product will, if properly manufactured, perform satisfactorily in service.

A quality assurance plan should define in detail the policies, procedures, and organization to be used throughout the program.

Specifically the plan should include a schedule for preparation of the plans and test procedures, and define the organization that will be used specifically for the Advanced Mariner program; it should also identify the test and inspection procedures to be followed for type approval testing of hardware at all stages of development and identify the revisions and additions that will need to be made to the present applicable quality control standards.

The quality assurance plan should include a set of flow charts illustrating the specialized testing to be performed on components, subassemblies, and assemblies throughout the program.

For the performance of type approval testing and preacceptance testing of components, subsystems, and systems, it is necessary to establish the environmental criteria to be used. The following NASA/JPL documents might be used as departure points for the definition of environmental criteria and test procedures:

ASO-30275-TST-A	Compatibility Test for Planetary Dry Heat Sterilization Requirements
30250B	Environmental Specification, Mariner C Flight Equipment Type Approval Environmental Test Procedures.
30251B	Environmental Specification Mariner C Flight Equipment, Flight Acceptance Environmental Test Procedures and Preacceptance Test Limits (Assembly Level).

Part of the quality effort should be the establishment of the quality assurance provisions in the detailed specifications for components, structures, subsystems, and the complete Mariner spacecraft. These would establish the test requirements for type approval testing, flight acceptance testing, preacceptance testing, and testing associated with receiving inspection. These requirements must be in accordance with the type approval, program plan, and the applicable environmental document.

a. Type Approval Testing

A type approval tests program plan will be required for the Mariner program. The program plan should list the components, subassemblies, and assemblies, the number of samples of each item to be included in the program, the environmental tests each sample will be subjected to, and a schedule for performance of the test programs.

For the performance of the type approval testing of components, subassemblies, subsystems, and the complete capsule and bus assembly as required by the type approval test plan, a detailed test plan will be required. The plan should define in detail the test procedures to be followed, the test equipment to be used, the data to be taken, sample data sheets as required, and criteria for passing or failing the tests.

The hardware required for the type approval test program would be delineated in the plan.

b. Vendor Control

Throughout the Advanced Mariner program it will be necessary to establish and maintain in conjunction with the reliability effort, control of all vendors to assure that a quality product is produced. Potential vendors should be evaluated and a review conducted to determine if the vendor has adequate and clean facilities, staff, finances, and quality procedures to satisfy program requirements.

To control vendor performance, it is necessary to provide adequate and complete specifications. It should be the responsibility of the quality assurance organization to guarantee that all specifications given the suppliers have been adequately reviewed and will, if followed, result in satisfactory hardware.

The quality control organization should also review all purchase orders to assure that (a) the vendor is qualified, (b) drawings and specifiactions referenced are in accordance with the correct configuration, (c) inspection requirements are defined, and (d) the quality assurance requirements to which the vendor must adhere are adequately defined.

c. Acceptance Testing

Acceptance tests are performed on components and subsystems throughout the manufacturing process and establish their acceptability according to applicable specifications.

They consist of functional tests, environmental tests, and physical inspection required to demonstrate that the component, subassembly, or assembly was produced in accordance with specification requirements.

For vendor manufactured components whenever source acceptance is used, tests should be approved and then witnessed by the prime contractor.

d. Manufacturing Control

During the manufacturing process a quality assurance log should be prepared for each item of equipment produced. The log should contain complete information relative to the quality integrity and provide assurance that all necessary tests have been completed.

In-process inspection should be utilized for all hardware. Measurements will be taken during manufacturing, data recorded, and compared with acceptance criteria, and any special precautions that must be observed. A prime example of this is measurement of cleanliness against clean room performance requirements.

An end item acceptance test plan should be prepared by the quality assurance organization for each piece of deliverable hardware. The plan should define in detail the tests to be performed, the test procedures to be followed, the test tooling to be used for the performance of tests, the data to be taken, sample data sheets, and criteria for acceptance or rejection of the completed article.

RE-ORDER No. 64-525

2.4 STERILIZATION

2.4.1 Introduction

Sterilization for the Advanced Mariner Launcher is discussed herein. The section examines significant aspects of sterilization techniques, facilities, proofing, and backup for the techniques, personnel training, operations monitoring, and impact of sterilization on reliability, quality assurance, manufacturing, schedules, spare parts, and management control. It should be emphasized that the primary purpose is not to present new concepts, nor conclusive support of old ones, but more to examine the implementation and implications of current opinion. The general conclusion reached is that sterilization of the lander is practical but not without difficulties; however, where difficulties are foreseen, backup alternatives exist.

2.4.2 Brief Review of Sterilization Techniques

Various possible sterilization techniques offer a varying degree of assurance of achieving sterility and, in many cases, pose unique system design problems because of the environments which these techniques impose on the sample to be sterilized. These techniques include exposure to a sterilizing gas, dipping in a germicidal bath, exposure to an ionizing radiation flux, and heat cycling.

Sterilization by exposure to ethylene-oxide gas is a possible technique. It has been shown that with a finite initial microbe population, exposure to ethylene-oxide for periods of from 8 to 18 hours could reduce the contamination level to about 10^{-4}. This technique, however, may not be guaranteed to reach all possible contaminated surfaces of a capsule payload, and of course could not penetrate "solids" which contain occluded contaminants. The reliability of this technique for achieving the required high degree of sterility is questionable.

Dipping components in a formaldehyde bath is another possible technique, but since the viscosity of a liquid is higher than that of gas, the same disadvantage--that of probably not reaching all surfaces--applies.

Exposure to radiation on Earth or during interplanetary travel is a valid consideration for sterilization. A dose level of 10^7 rad is deemed sufficient to reduce the contamination level to the desired degree. Because of the inherent shielding provided by a sterilization shroud and the capsule payload structure, it is extremely unlikely that every interior surface will receive an exposure of 10^7 rad. If radiation sterilization is to be attempted during payload assembly, the surface radiation flux would have to be much higher in order that every interior surface receive a dose level of 10^7 rad. Since many elastomers, optical devices, solid-state components, and planetary science instruments may be sensitive to these levels of radiation, radiation sterilization will probably not be feasible for a Mars capsule payload.

Maintaining completely sterile conditions during the entire capsule development, manufacture, assembly, and test cycles offers another possible avenue for achieving sterility. Cursory examination of the problems attendant to this sterilization technique offers little hope for success with this approach.

Heat sterilization then is the only remaining approach. It has been found that exposure to an initially contaminated specimen to a temperature of 135°C for 24 hours will, according to the exponential kill curve, reduce the initial population by a factor of 10^{13}. Heat sterilization reaches all surfaces of a payload package and is effective against micro-organisms occluded in "solids" as well.

2.4.3 Selected Technique

a. Fundamental Issues

Micro-organism sensitivity to dry heat has been measured in terms of temperature level and exposure. Current opinion holds that 135°C for 24 hours, which provides a 10^{13} factor of organism reduction, will provide the desired confidence level of complete sterility if a low burden of contamination exists initially. It is also believed that Class 100 clean room fabrication of the hardware will provide the required low level of contamination. The desired confidence level of complete sterility has been expressed as the probability of one viable organism reaching Mars not exceeding one in 10^4. To repeat, it is not the purpose of this report to support or refute the current opinion but to demonstrate procedures and facilities which can implement this opinion and at the same time measure its validity. Figure 6 explains clean room classifications.

The recommended procedure is summarized by the following chronological steps:

1) Component fabrication in any one of the following procedures:

   a) A Class 100 clean environment, or

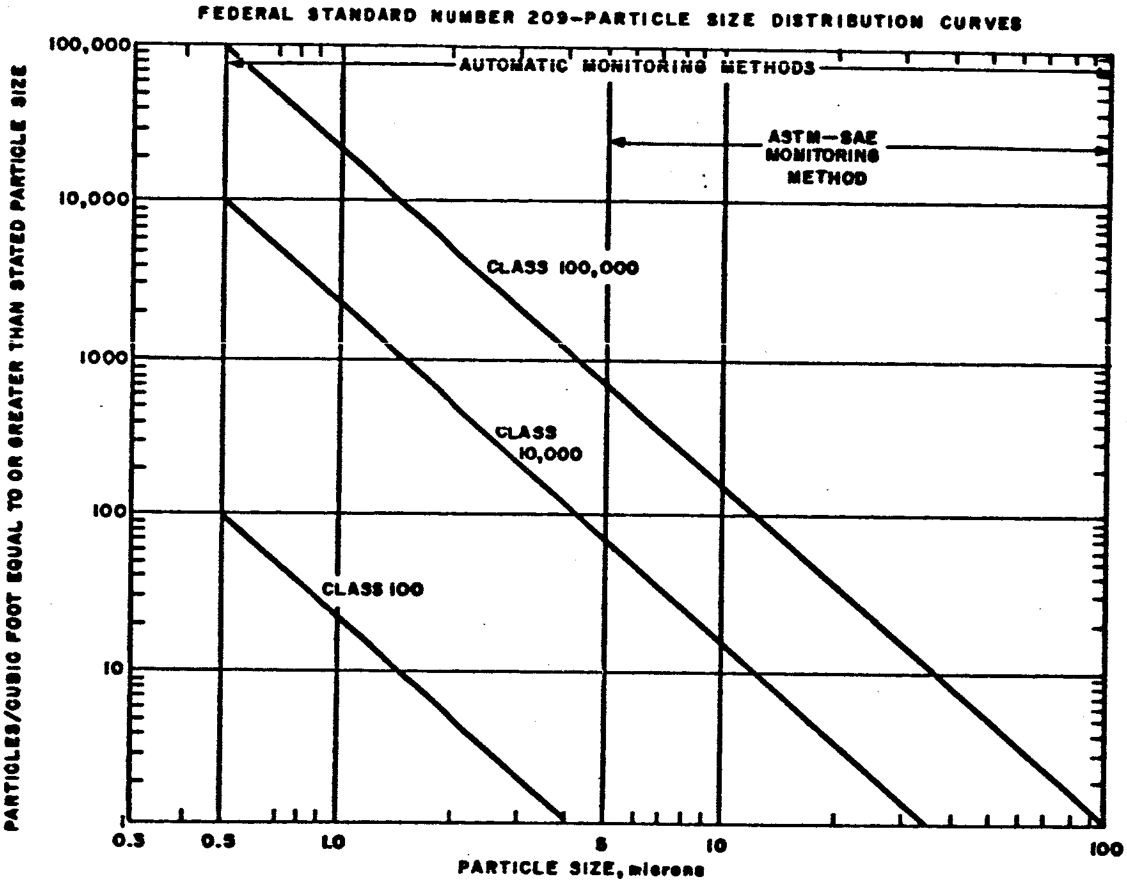
   b) A normal environment followed by thorough cleaning, or

   c) A normal environment followed by presterilization

2) Subsystem and lander assembly in a Class 100 clean environment

3) Encapsulation of the lander in a rigid, sealed envelope (can) in a Class 100 clean environment

RE-ORDER No. 64-525



64–11499

Figure 6 PARTICLE SIZE DISTRIBUTION CURVES

4) Dry heat sterilization of the lander in the can at 135°C for 24 hours

5) Acceptance testing, handling, and bus installation with the lander still sealed in the can until ejection enroute to the planet.

The feasibility of this procedure hinges on several fundamental issues, some of which may be resolved here and some by later experimental evaluation. These fundamental issues are as follows:

1) Are all components amenable to heat sterilization?

2) Can the spacecraft and all its components be manufactured entirely in a Class 100 clean environment?

3) Will Class 100 clean manufacturing provide the necessary low burden of contamination?

4) Is the Class 100 clean manufacturing requirement an unnecessary embellishment and, if so, what procedures will be sufficient?

On the question of component heat sensitivity, a component-by-component survey of vendor sources yields high confidence that terminal sterilization will be feasible but that additional experimental verification is required for several cases.

A sterilizable solid-rocket propellant has been demonstrated by the Thiokol Chemical Company, and now the assembled rocket must be demonstrated. Tests of NiCd batteries by NASA/Goddard has shown feasibility with reasonable performance degradation, but additional performance data may be necessarcy.

On the question of the feasibility of manufacturing components in a Class 100 clean environment the answer for many components is impractical rather than infeasible because of cost and schedule limitations; however, alternatives exist which are more attractive, such as cleaning or presterilization after manufacturing in a normal "dirty" environment. Assembly of the subsystems and capsules in the clean environment is practical.

On the question of Class 100 clean manufacturing providing a sufficiently low burden of micro-organisms, the answer is unknown, and extensive testing will be required. This testing can be accomplished as part of the test program recommended for certifying the sterilization procedures and facility. This testing will also answer the final question. Biological burden counts will indicate whether Class 100 clean manufacturing is an unnecessary embellishment.

More detailed discussions of the above considerations are provided later in this section.

b. Clean Room and Sterilization Facility

The facility is ultimately visualized as two buildings - one within the other. The exterior building for environmental protection consists of approximately 16,800 ft^2 and the internal building of approximately 12,000 ft^2 having areas designated for the following functions:

1) Receiving and acceptance room (class 10,000 area) (see figure 6) in which received goods are unpacked, grossly cleaned, and tested for compliance with specifications.

2) Clean-up and packaging room (class 10,000 area) in which accepted hardware undergoes a more elaborate clean-up procedure and ultimate packaging into certified sterile polyethylene bags to be heat-sealed before storage. Articles will be bagged under hoods of class 100 characteristics.

3) Storage room (class 10,000 area) for storage of components while awaiting receipt of all items necessary to complete sub-assemblies and final assemblies.

4) Major assembly room (class 100 area), a large area of approximately 3600 ft^2 in which lander will be assembled. As many as four landers may be in process of assembly at one time.

5) Hardware monitor room devoted to equipment used for monitoring the cleanliness and biological status of assembly facility, efficiency of cleaning operations, and physical and biological results of all sterilization processes.

6) Personnel lockers and changing rooms adequately designed to permit efficient flow and suitable preparation of personnel while maintaining adequate safeguards to minimize contamination in the work areas.

7) Ground support equipment room to house all necessary electronic and test mechanical apparatus associated with spacecraft check-out and an isolation corridor protruding into the assembly area to permit test equipment access to any of several spacecraft being assembled. Sealed plug-in leads will permit attachment of test equipment to the craft without endangering cleanliness of the assembly area.

8) Dry-heat oven (20 by 20 by 20 feet), to heat the spacecraft to a temperature of 135°C for 24 hours. The control timer will be initiated by a sensor in the chamber or attached to same point within the lander. If the chamber temperature is used as a guide, suitable heat lag data will be required to assure that the entire load has been at the proper temperature for the full 24 hours. If an internal measurement is used, the reading will be read out through cables.

In addition to the facility described above, an additional oven such as described above in paragraph eight, should be available at the launch site as well as at the prime contractor plant.

c. Certification and Monitoring of Procedures and Facility

Certification of procedures and the facility will proceed in three major phases: (1) pilot plant operation, (2) preliminary production plant evaluation, and (3) final production plant evaluation. The pilot plant operation will consist of a simulation of full-scale production using dummy hardware and a prototype sterilization facility composed of a few small isolators, a gas sterilizer, a dry heat sterilizer, and associated equipment in limited quantities. The preliminary evaluation of the production facility will employ dummy hardware and a few prototype subsystems, if available, to check the complete production plant. The final evaluation will utilize full-scale manufacture of the sterilization assay prototype to provide final judgment.

The evaluation in each of these phases will consist essentially of measurement of the biological burden of the hardware, equipment, and rooms during various phases of the manufacturing cycle. Burden in the rooms would be measured by using membrane filter monitors in the air conditioning systems, settling plates for biological fallout in the atmosphere, Royco-type analyzer for atmosphere particle count (nonbiological), and swabbing of various surfaces, followed by culturing. Burden in equipment such as isolators would be measured with membrane filter monitors in the air inlet and exhaust, settling plates, and swabbing of interior surfaces. Burden in the dummy hardware and assay prototype would be determined by disassembling the hardware down to its smallest elements, fragmentation of the elements into pieces or powder, and blending the particles to get a homogeneous distribution and then plate counting.

Mixing of the particles will be separated by elements or a group of elements comprising a single component in order to obtain statistical data at the component or element level. For some elements, fragmentation may be unnecessary, and surface swabbing may be adequate, or if the element is small in size, it may be immersed in a nutrient broth, an aliquot taken, and then plate counted. These techniques will apply, however, only to elements which are homogeneous and free of internal organisms. For instance, metal parts such as bolts, rivets, wire, sheets, and bars will be free of internally trapped organisms because of the high temperature at which the metal is produced. Certain plastics are formed at low temperatures, and it is possible for viable organisms to be encapsulated in the interior of the plastic. In this case, it will be necessary to grind the plastic into a powder for proper sampling and assay.

Plate counting of the fragments and powder samples will be accomplished with a dilution technique, particularly for assays prior to sterilization. This is a frequently used technique which consists of successive quantitative dilutions of the sample in sterile water or nutrient broth until the quantity of organisms is reduced to levels small enough to permit counting on a plate culture. The initial sample is suspended in sterile water (or nutrient) and thoroughly mixed. One ml of the suspension is then added to 99 ml of sterile water, and so on. One-ml samples are then taken from each successive dilution and mixed with nutrient in petri plates. The 1 -ml sample from the fifth dilution will represent a 10^{10} factor of dilution and fifty colonies growing on this plate will indicate that the original sample contained 50×10^{10} organisms. Additional details on microbiological monitoring and culturing are discussed in paragraph 2. 4. 5.

The hardware assays must be conducted in a completely sterile chamber using sterile tools for disassembly and fragmentation. Sterile glove box isolators will be required. Extreme care must be exercised to prevent contamination of one component by another which would lead to false evidence as to the real origin of the contamination. The operator must learn to sterilize his gloved hands and tools after touching one component and before touching another. Efficient and exact procedures must be formulated, and the operators trained by practice on unsterilized prototypes to follow procedures precisely. Since this is a critical operation requiring unusual precision, it is recommended that redundant assays be made by sources external to the capsule contractor and experienced in sterile operations.

Monitoring of procedures during the production of flight hardware would utilize most of the techniques described in the certification described above. The checks would be made at regular prescribed periods at various stages in the manufacturing cycle. Destructive assays of one complete flight unit will be made. Also subassemblies would be periodically assayed. Monitoring data would be methodically catalogued and reviewed by a sterilization control board (see below) prior to its certification of the sterility of each flight unit. These records would be available to NASA and should prove valuable in establishing sterilization specifications for future programs.

d. Organization and Management

Assuring the sterility of a lander which is required to perform as difficult a mission as the Advanced Mariner lander poses unique management problems.

Sterility requirements must be established for all phases of component procurement, manufacture, assembly, and test. These sterility requirements must be continuously monitored, and then the final product must be certified. Implementation of the sterility requirement then is functional as well as legislative.

Since the sterility requirement can in no way be relaxed or compromised, regardless of schedule pressure, and so forth, it would appear wise to provide relief from such possible pressures. This may be accomplished by creating a Sterilization Control Board empowered to implement sterility requirements, which reports only to the project director. This Sterilization Control Board (SCB), which would be the legislative body for carrying out the sterility mandate, should be composed of senior personnel from Engineering, Quality Assurance, Manufacturing, and Biological Sciences. This group would determine the disposition of any conflicts regarding sterility or alleged breaches thereof, forwarding their recommendations to the cognizant manager. It would also serve as the prime liaison channel with the NASA sterilization control officer. The functional aspects of the Board's responsibilities--writing sterilization requirements into the specifications, preparing procedures, monitoring of techniques and of equipment utilized--would be carried out by the Sterilization Control Group (SCG), which would, of course, report to the Board. This special group of technicians, graduates of the Sterilization Training Program, would be composed of personnel possessing previous experience in the various phases of vehicle development. The day-to-day efforts of this group would provide statistical justification for the sterilization plan and the assembly facility.

e. Personnel Training Program

It is the purpose of this training program to impart basic and applied information and skills concerning clean room assembly and sterilization techniques. An additional goal is to make the personnel contamination conscious. Personnel can be trained by means of a two-fold program which includes a formal workshop course (one week) and an "on-the-job" training program.

The workshop course consists of the following:

1) Basic bacteriology course and workshop

A brief introductiory program designed to acquaint members with identification, habits, size, growth characteristics, and transmission of micro-organisms.

2) Basic clean room course and workshop

Designed to acquaint personnel with existing state-of-the-art developments concerning cleanliness based upon particle size.

3) Aseptic procedures course and workshop

Designed primarily for those people actually performing assembly to assay their ability to work under the restrictions imposed by the high degree of cleanliness required during assembly operations. This includes work with partial closures, typical clean room benches, and isolator systems.

4) Isolator operations workshops

Designed to familiarize personnel with particular problems and to evaluate their ability to work within barrier systems.

5) Monitor system course and demonstration

To be used to acquaint all personnel, and particularly supervisors, with the technique used to monitor clean and aseptic operations.

Personnel concerned directly with the clean assembly can be further trained as they continue to work with the facility. Professional level supervision and instruction may be given as the personnel "check out" the facility and while actual assembly of the lander is underway.

The individuals attending the course consist of an appropriate mix of professional, supervisory, and technical contributor level personnel. Individuals should be selected on the basis of motivation, manual dexterity, intelligence, and their ability to methodically follow through an operation. Individuals who are selected and successfully complete the program may receive suitable recognition, thus increasing their motivation and giving them an "esprit de corps." Such recognition would increase the impact of their training and help reduce the human error factor. The initial group of individuals being trained can serve as a "cadre" to train other personnel. These people should be selected from the different groups involved in the program--Manufacturing, Engineering, Quality Control, and others.

2.4.2 Related Effects

a. Manufacturing of Components

It is judged that assembly of the major subsystems and the vehicle itself is entirely practical in the Class 100 clean environment. Manufacturing of many of the components in a clean environment is not practical, however, principally because they are mass produced. The tooling and facilities involved are usually extensive and costly. The cost of incorporating all or part of this equipment into a clean facility for a relatively short production run would be unacceptable. In addition, two more attractive altermatives are possible: normal manufacturing followed by either thorough cleaning or presterilization. As a typical example, consider mechanical hardware such as bolts, screws, rivets, nuts, wire, sheet, bar stock, and so forth. It is patently obvious that it would be far more practical to clean such material by dipping or wiping following conventional manufacturing than to install a screw factory or rolling mill in a clean room. A similar argument can be made for many electronic components. Certain electronic components, however, have enclosed interiors, possibly dirty, and are not amenable to liquid cleaning. For instance, wire windings in transformers, motors, coils, and so forth, restrict access of liquid cleaners to inner windings which may not be particularly clean. Ultrasonic cleaning is one possibility, or presterilization by gas or dry heat may be necessary. Presterilization does not imply that subsequent handling must be sterile, just aseptic, since the prime objective is to reduce the biological burden in inaccessible interiors.

Cleaning or presterilization of "dirty" components should obviously be performed by the prime contractor or, in the case of subassemblies, by the subcontractor. Both the contractor and subcontractor will have the facility for presterilizing, cleaning, and subsequent aseptic handling.

Many electronic components such as transistors, diodes, and integrated circuits are presently being manufactured in clean rooms for reliability purposes. These components will probably be amenable to clean procurement, but present manufacturing, packaging, and delivery procedures will require close examination to ensure that standards for this application are satisfied.

Certain raw materials which are produced at low temperatures and in a manner that viable organisms might be encapsulated in the interior of the material introduce a special problem. Some plastics are formed at temperatures less than those required to kill biological organisms, and encapsulation of excessive burdens is possible. This possibility should be checked experimentally by grinding typical samples and making a burden count as described in the section on certification of the facility. If a problem exists, several solutions are feasible; e.g., employ only plastics formed at temperatures much higher than sterilization temperatures or presterilize the low temperature plastics if they can withstand these temperatures. Metals are not a problem since they are formed at high temperatures.

Bonding of materials may have similar problems of microorganism encapsulation. For example, bonding of Teflon to aluminum employs a silicone base adhesive cured at 160°F. This temperature is less than sterilization values, and organisms on the bonded surfaces would survive and be inaccessible to surface cleaning or surface sterilization. This is not an area of great concern, however, because the surface must be thoroughly cleaned (sometimes quite strongly by acid etching) to facilitate strong bonding. Again, presterilization by heat would be the solution provided that the bond can withstand the temperature.

b. Heat Sterilizable Parts List

A survey has been conducted to determine the availability of typical heat sterilizable components and those which are manufactured in clean environments or are amenable to cleaning after manufacture. The allowable ambient storage temperature ranges for these components (table 2) indicates that little difficulty can be expected in locating most of the components which will meet both design and heat sterilization requirements.

1) Solid-State Components

Some components such as silicon transistors, rectifiers, and integrated circuits are presently manufactured in clean environments and are easily adaptable to Class 100 requirements. Of these, integrated circuits are ideally suitable for a sterilizable subsystem design in that they replace conventional subassemblies such as flip-flops, containing several resistors, transistors, and diodes with a single component manufactured in a clean environment. These components are hermetically sealed and capable of being sterilized.

2) Transmitter

Since integrated circuits are not generally available for RF applications, the S-band transmitter would be a solid-state design using conventional components. Silicon transistors and diodes are given at 200°C soak for 160 hours as a matter of course to ensure reliability. There should be no problem obtaining suitable components for the transmitter.

RE-ORDER No. 64-525

TABLE 2

TYPICAL HEAT STERILIZABLE COMPONENTS

Component	Nonoperating Temperature Range (°C)	Source	Comment
Silicon Transistors (all types)	-65 to 200	GE	Hermetically sealed
Silicon Rectifiers (all types)	-65 to 200	GE	Hermetically sealed
Resistors (metal film)	-55 to 190	Ohmite	Hermetically sealed
Capacitors (glass)	-55 to 200	Corning	Hermetically sealed
Capacitors (ceramic)	-55 to 150	Vitramon	Sealed
Capacitors (tantalum)	-55 to 200	Mallory	Hermetically sealed
Amplitron	to 200	Raytheon	For transmitter
Wire (Teflon insulated)	-90 to 200	Super-Temp.	May not be Class 100 clean
Connectors (MS)	to +500 (some types)	Cannon	Hermetically sealed
Connectors (all req'd. types and headers)	-200 to 425	Physical Sciences Corp.	Hermetically sealed
Air-Cored Tank Coils	to 200	Illumitronic Eng. Corp.	
Transformers (Mil T-27A group U)	-55 to 200	Freed, GE	Hermetically sealed

TABLE 2 (Concl'd)

Component	Nonoperating Temperature Range (°C)	Source	Comment
RF chokes	-55 to 180	Jeffers Caddell-Burns	Sealed
Pressure Transducers	-55 to 150	Bourns, Inc.	
Adhesives	to 200	Dow Corning	
Battery	to 145	Sonotone	Hermetically sealed
Accelerometer	-65 to 150	Donner/Bell	
Lander Heat Shield	-65 to 200	Avco	
Lander Structure	-65 to 300	Avco	
Lander Aft Cover	-65 to 200	Avco	
Bonding Agent	-65 to 200	Dow Corning	
Sterilization Canister	-65 to 300	Avco	

3) Power Amplifier

The power amplifier would use an amplitron in its output stage since the output power required is in the order of 90 watts. Amplitrons are available which operate at temperatures exceeding the heat sterilization temperatures. As with the transmitter, no problems will be encountered in obtaining suitable components for the power amplifier.

4) Power Supply

The power supply, a DC-to-DC converter and regulator, can be a solid-state design. The transformer used in the converter is most likely not manufactured Class 100 clean; however, there is no problem in obtaining a sterilizable design which can be heat-cycled many times to temperatures above 200°C.

5) Battery

The battery used is a nickel-cadmium type which is hermetically sealed and can be heat-sterilized. This type of battery is the only one presently available which can survive the heat sterilization cycle. The battery suffers a loss of no more than 10 percent of its rated ampere-hour capacity after sterilization. This component is not normally assembled in a Class 100 clean environment. Additional statistical data on performance degradation may be desirable.

6) Accelerometer

Accelerometers are available (e.g., Donner's,) which can be made sterilizable by moderate modifications. Bell Aerospace has an accelerometer that is sterilizable without modification. The unit under consideration is a closed-loop, force-balance servo type.

7) Lander

The entire unit can be manufactured to be heat resistant. Structural components, such as heat shield, internal structure, bonding agent, and afterbody should pose no design problems as regards heat sterilization.

8) Propulsion

Results of a test program to locate a solid propellant capable of withstanding dry heat sterilization are presented in table 3. The type approval specification of 145°C cycled for three times at 36 hours each was used as the environment for the tests. The results

RE-ORDER No.

TABLE 3

PROPELLANT STERILIZATION TESTS
(145°C for 108 Hours (Three 36-hour cycles))

Propellant System	Physical Prop.	Control	Physical Properties (JANAF) After Exposure at 145°C for Three 36-Hour Periods
PBAA	Stress, psi	43	25
	Strain, in/in	0.33	0.25
	Modulus, psi	268	207
PRAN	Stress, psi	53	155
	Strain, in/in	0.61	0.48
	Modulus, psi	145	1177
Polyurethane	Stress, psi	169	69
	Strain, in/in	0.14	0.266
	Modulus, psi	2300	692
Double-base	Stress, psi	454	
	Strain, in/in	0.58	Note 1
	Modulus, psi	1180	
Plastisols	Stress, psi	140	251
	Strain, in/in	1.79	0.07
	Modulus, psi	629	4155
Polysulfides	Stress, psi	320	Note 2
	Strain, in/in	0.45	
	Modulus, psi		
PBAA TP-H-3105	Stress, psi	132	
(New propellant,	Strain, in/in	0.27	Note 3
no aluminum)	Modulus, psi	909	

Note 1: Marginal at 200°F for 72 hours
Note 2: Unsatisfactory at 200°F
Note 3: No appreciable change

showed extensive changes to the physical characteristics of the propellants except for Thiokol TP -H-3105, which performed satisfactorily. The next step is to measure the sterilizability of a complete engine with this propellant installed.

c. Reliability

A serious technical problem concerns the effect of sterilizing heat cycles on the reliability of a spacecraft system. The seriousness of the problem is directly associated with the lack of concrete information available on the subject. However, from the limited data on hand, there is an indication that some degradation occurs in the reliability of certain components subjected to heat sterilization.[1,2] In some instances, a number of critical spacecraft components have been seriously affected by the heat cycling required during the sterilization process. The primary emphasis of the reliability effort should be to assure that a highly reliable design incorporating only heat sterilizable parts is developed which can withstand the rigors of heat sterilization. Thus a reliability organization should take necessary measures to uphold reliability requirements throughout the sterilization process, while attempting to ascertain the effects of heat sterilization on reliability.

1) Parts and Materials Selection

Since it has been determined that most spacecraft components now in use will survive heat cycling, steps can be taken to assure the selection of parts and materials which can be completely sterilized without causing adverse effects on reliability. Component specifications to vendors should reflect this heat-resistant requirement. Vendors may be requested to submit, together with components lists, a description of the ability of these components to withstand sterilization without degradation to their reliability.

Vendors can be required to provide any existing information related to these questions as part of their contractual obligations. Furthermore, the vendors can be required to establish similar requirements on their suppliers.

components for which sterilization-reliability effects are not sufficiently substantiated by pertinent data can be subjected to qualification tests, consisting of subjecting representative samples of these components (quantities to be determined during the program) to a thermal environment of 145°C for 36 hours, cycled three times.

[1] Hobby, G. L., A Review of Space Research, National Academy of Science, National Research Council, Review of the NASA/JPL Spacecraft Sterilization Program, Publication No. 1079, Appendix III 9 (1962).

[2] Jaffe, L. D., Sterilization of Unmanned Planetary and Lunar Space Vehicles - An Engineering Examination, Technical Report No. 32-325 (Rev.), Jet Propulsion Laboratory, California Institute of Technology, (March 1963) (DEP No. 347.00.00.00-E4-02).

The same samples can then be placed on a life test which is commensurate with the operating lifetime (and stresses) of the components during capsule experimentations.

2) Parts location and heat flow

Another key factor in the design of an inherently reliable lander is that of parts location, particularly electronic components and heat flow. Along these lines, a structurally flexible mockup of the capsule can be built to permit experimentation in the location of parts and heating bath. Parts should be located so that less heat-resistant components will receive the lowest values during temperature buildup in final heat sterilization. Special heaters may have to be used inside the flotation sphere.

3) Reliability design reviews

The reliability design review includes as check list items the sterilization-reliability factors discussed previously. The design review can be used to evaluate the capsule design critically from a reliability viewpoint. Design improvements can be initiated to alleviate potential reliability problems induced by the sterilization process. The reliability organization will follow up all action recommended at the design review.

d. Spare Parts Program

One of the most significant aspects of the sterilization requirements insofar as the spare parts program is concerned is its impact on the sparing level maintained at the launch site. The sparing level at the launch site must be the complete lander-container assembly. In the event of component malfunction at the site the spare part replacement is the complete vehicle iteself.

Sparing at the next lowest level, which is subsystem replacement, will require unsealing of the sterilization container which will violate lander sterility. The system must, therefore, be capable of withstanding an additional cycle of sterilization. Unless a redundant sterilization facility is available at the launch site, the repairs and resterilization must be done back at the contractor's factory. The delays involved in all of this may be critical, considering launch window restrictions. It is planned for Advanced Mariner, however, to have a separate sterilization oven at the launch site.

Another important implication is the limit on the number of resterilization cycles and its effect on spare parts needed in the production line. If a flight unit fails acceptance tests after sterilization, it must be scrapped if only one sterilization cycle is permitted or repaired and resterilized if two cycles are permitted. If it fails a second time, it must be scrapped, and so forth. The question is how many production units must be started to ensure delivery of the desired number of flight units. This number can be minimized by testing as thoroughly as possible before sterilizing. Failure after sterilization will then be due primarily to the effect of the sterilization environment. Predictions for this attrition are not available at this time but a parametric approach in which various attrition rates are assumed yields some interesting results. For Advanced Mariner an attrition, factor of ten percent has been used.

e. Quality Assurance Program

The sterilization requirements make it necessary to vary the testing procedures normally associated with aerospace programs. This variation is primarily due to the fact that an environmental test laboratory is not an aseptic environment, and it would be difficult and expensive to make it such. Thus environmental testing of flight equipment at assembly levels lower then the complete system of capsule and sterilization container is not practical. Such testing can be performed on representative samples of equipments as required.

1) Type-approval test program

The type-approval test program is utilized to demonstrate that the lander sterilization shield assembly will perform satisfactorily throughout the mission cycle from factory to landing on Mars. To accomplish this, representative production hardware can be subjected to a series of environmental tests representing the environments that the assembly will experience throughout its mission.

The type-approval hardware should be assembled in the clean room. In this manner, it will be possible for the program to demonstrate that personnel can reliably perform the necessary assembly operations under clean room conditions. After the hardware has been assembled, no attempt is made to maintain it in an aseptic condition. As part of the type-approval program, all hardware is subjected to a compatibility test of three heat cycles of 145°C for 36 hours each.

This test is performed to demonstrate that the similar flight hardware will survive the actual sterilization heat cycle of 135°C for a 24-hour period and operate thereafter reliably. Upon completion of the test, the hardware is subjected to functional tests to demonstrate that no deleterious effects resulted from exposure to the heat cycles. The remainder of the environmental tests are the standard environmental tests associated with aerospace equipments. Since the type-approval testing is not performed under aseptic conditions, it is not foreseen that hardware sterility requirements present any insurmountable problems regarding the quality test program.

2) Test of flight hardware

The test of flight hardware is somewhat complicated by the sterilization requirements. Components, subassemblies, and assemblies to be used for flight articles cannot be subjected to environmental tests after they have been cleaned and still maintain their aseptic condition. Thus it is not obvious that any PET testing can be performed on flight equipments except at the system level with the capsule inside its sterilization shroud.

The required environmental testing of assemblies, subassemblies, and components can be performed on a sampling basis, with the selection of such samples made at random from the aseptic production line. After the performance of such tests, these items cannot be reintroduced into the assembly line of flight hardware unless they can be cleaned of accumulated burden. Quality assurance test procedures (QATP's) control the testing associated with production; a separate QATP can be prepared for each functional test and sampling environmental test as required throughout the production cycle. Quality control planning procedures (QCPP's) control the assembly and in-process inspections. Both the QATP's and QCPP's have provisions for maintenance of aseptic conditions as required and provide for signoff by the Sterilization Control Group personnel as proof that the specific aseptic handling techniques have been observed. The requirement to maintain a minimum biological burden for all hardware makes it necessary to subject some component and piece parts to chemical and/or heat cycles prior to their use in higher assemblies (presterilization). This requirement can be delineated in the applicable detail specification and a QATP or QCPP prepared outlining the sterilization procedures to be followed.

3) End-item acceptance test plan

The acceptance of the sterile capsule assembly involves flight acceptance tests consisting of functional and environmental testing. The functional testing is performed to demonstrate that the assembly meets all the requirements of the detail specification. Environmental tests are performed on the complete assembly at qualification levels.

As a minimum, the environmental tests consist of handling shock, powered-flight vibration, staging and ignition shock, humidity, temperature (equipment operating), altitude, and a pressure seal test (sterilization canister).

If a failure occurs during the testing, it will be necessary to completely disassemble the assembly under aseptic conditions. Since the external surface of the sterilization canister is not aseptically clean, it will be necessary before disassembly to surface sterilize the canister.

f. Schedule

The prime question here is whether the desired sterilization program is compatible with the schedule available for the Advanced Mariner program.

As near as can be determined, the program will match the available schedule but should be considered a long lead item. A careful review of the lander design indicates that the assembly of the subsystems into the lander and the lander in the sterilization canister should be accomplished without too much difficulty.

Bench and system testing can be accomplished with the test equipment located outside the isolator and with air-tight signal and power leads connected to the capsule hardware inside the isolators. A combination of switching circuits and an adequate number of test leads will facilitate complete cycling of the test from exterior controls. Interior operations would then be reduced to connecting and disconnecting the test leads.

A major milestone schedule for the sterilization program is shown in figure 31.

The sterilization facility acquisition times indicated thereon are reasonable, but just allow for the system test units to be fabricated in the clean room. Acquiring the facility at this rate also means that sterilization planning must be done by both the contractors competing for the program during the preliminary design phase. This schedule may be slipped up to a year and not effect the assembly of flight hardware, but will degrade the quality of system test results, and deny experience to the assembly teams, as a result of assembling test hardware under conditions, and in a location different from the flight hardware.

2.4.5 Discussion of Basic Microbiology as Applied to the Advanced Mariner Lander

a. Monitoring of Microorganisms

Samples of the organisms will be obtained from membrane filter monitors, settling plates, swab tests, and from air impaction devices. The

RE-ORDER No. 64-523

samples will be taken from the glove boxes used in assembly of the capsule and the storage of components and subassemblies. The subassembly and components will be monitored and sampled for microorganisms. Cultural conditions and media to be used in the primary evaluation techniques follow. For the aerobic bacteria, Eugonagar (BBL) will be used. For the anaerobic bacteria Eugonagar (BBL) and/or thioglycollate medium, Brewer's modification will be used. The Eugonagar and the thioglycollate medium will be used under anaerobic conditions. Incubation temperatures will be room temperature, 37°C, and 50°C to 55°C for the thermophilic organisms. Cultures will be incubated for up to one week before they are considered to be negative. For the culture of yeasts and molds, Mycophil (BBL) and/or Sabouraud's agar will be used. Incubation temperatures for the yeasts and molds will be room temperature and 37°C. No culture will be considered negative until after one week of incubation. Where pertinent, counts will be made directly from the membrane filters and settling plates. The counts from the membrane filters will be reported as colonies per given volume of air sampled and the settling plates will be reported as colonies per unit area of media per unit of time. The other techniques for colony counting will be described in section C of this addendum.

b. Identification of the Isolated Microorganisms

Primary isolates will be subcultured onto slants of Eugonagar, theoglycollate medium, Mycophil, or Sabouraud's medium as required. Observations of colonial morphology, and pigmentation will be made on the plates from which the primary isolates are taken. Observation of the characteristic growth on slants will be made on the subcultures of the primary isolates. Smears of the isolates will be made, gram-stained, and also spore-stained. Size, shape, arrangement, and gram characteristic of the vegetative cells will be reported, and the presence of spores, their location and size will also be reported.

1) Bacteria and actinomycetes

From the information obtained as regards colonial morphology, growth on a slant, pigment production, cell size, shape, arrangement, gram characteristics, spores, etc., the organisms might be divided into the following categories of the most probable organisms to be encountered.

a) Gram positive, spore formers if rods (single cells and chains) could be considered members of genus Bacillus.

b) Gram positive cocci in singles, pairs, and chains could be considered member of the genus Streptococcus.

c) Gram positive cocci, if cocci in clusters could be considered members of the genus Staphylacoccus or Micrococcus.

d) Gram positive cocci in packets or sheets could be considered members of the genus Gaffkya or Sarcina.

e) Gram positive, rods, spore formers, anaerobic, could be considered members of the genus Clostridium.

f) Gram negative, nonspore forming rods could be members of the following genera: Escherichai, Aerobater, Proteus, Pseudomonas, and Paracolon.

The gram negative nonspore-forming rods shall be subcultured on to TSI (triple sugar iron agar B. B. L) which will aid in the decision in which genus to place the organisms; further testing will be done if necessary. From the literature it is suspected that the main body of organisms isolated will fall into the genera Bacillus, Pseudomonas, Proteus, and perhaps the Coliforms. Further testing as motility, nitrate reduction, gelatin, IMV(1) C, potato plug, fermentations, and so forth, shall be carried out as the need arises.

2) Yeasts and molds

From the information obtained regarding colonial morphology, pigment production, and morphology of the organism (e.g., type of spores, condiophores, sporangia, rhizoids, and so forth), preliminary decisions could be made as to genus. For further information, subcultures could be made on to corn meal agar, CHlamydospore agar, Czapek Dox agar, and so forth.

c. Counting or Enumeration of the Microorganisms

Counts of the microorganisms will be made in various manners. Components will be reported as the number of organisms per component. Swabs will be reported as the number of organisms per unit area swabbed. Air samples will be reported as the number of organisms per unit air volume sampled. Settling plates will be reported as the number of organisms per unit area of medium per unit time. The assembled capsule which is to be monitored will be reported as the number of organisms per capsule.

Actual counting procedures for viable organisms will be performed by dilution plate count technique and/or M. P. N. (most probable numbers) technique. The plate counting and most probable numbers techniques will be accomplished using the suitable media and temperature ranges. The plating and most probable numbers procedures will be that cited in the Standard Methods of the American Public Health Association and American Water Works Association.

2.5 SUBSYSTEM DEVELOPMENT PROGRAM

2.5.1 Introduction

This section of the development plan covers make-or-buy decision making. bus and lander subsystem development programs, ground support equipment, and subsystem problem areas.

When the final design activity has reached the point where final subsystem requirements are available it is possible to initiate the several required subsystem development programs. Some of these are going to involve procurement outside the prime contractor. Therefore, at the time these programs are initiated, the necessary make-or-buy decision must be made. While the discussion of subsystem development programs herein differentiate between prime and subcontractor efforts, the make-or-buy decision process is discussed here because of appropriate chronology.

Since ground support equipment must first be available at a subsystem level, particularly in the case of electrical GSE, this discussion is included here. It is not restricted to subsystem considerations, however, and covers system requirements as well.

Subsystem problem areas are discussed last and cover all the areas contained in the section.

2.5.2 Make-or-Buy Decisions

Contractual make-or-buy decisions should be made by a committee which would include the following representation: Design Engineering, Manufacturing, Materials Control Department, and Information and Control Systems. The make-or-buy committee acts in essentially the following manner. At the time of release of the preliminary component or subsystem requirements specifications, the committee will review and recommend a program to be followed. The following criteria should be considered in this analysis: costs, equipment requirements, past experience, capacity and capability, quality and reliability requirements, facilities, and transportation.

After analysis by the committee, a make-or-buy recommendation should be made, identifying the following:

RE-ORDER No. 64-525

1. The contract number.
2. The data of preparation.
3. The part number and IIS coding.
4. The part name.
5. The recommendation of make-or-buy.
6. The name and location of possible sources.
7. The unit cost estimate.
8. The quantity.
9. The total cost per end item.
10. The special tooling requirement and cost.
11. The lead time.
12. Whether Government-owned facilities will be used.
13. Whether additional facilities are required.
14. The reason for the decision.

Enough information is then available to release RFQ's to possible sources, based on the available design and subsystem requirements information. Very often in a business where the state-of-art is being pushed, only one supplier is judged capable of doing a certain job. Where this is true, the make-or-buy decision must be made using engineering judgement.

2.5.3 Bus Subsystem Development Programs

(See figures 16 through 30 for detailed schedules found in the schedules section, below)

2.5.3.1 Bus-Television Subsystem

The general system design and subsystem requirements will have been established for this subsystem during the final design phase. The work covered in the development program thus includes the selection of component design for evaluation, the purchasing of components for design data testing and evaluation, the performance of the required development and subsystem qualification tests, the preparation of final design documentation and the monitoring of system qualification testing.

1. Procurement Cycle

The first task which must be completed is the generation of a set of component specifications suitable for purchase of development test hardware. These specs will be discussed with potential vendors and purchase requisitions eventually released for the purchase of test and evaluation units.

2. Testing

The testing and evaluation procedure will be concentrated on the Vidicon camera tube. The major effort will be to verify ruggedness, resolution and sensitivity under all likely conditions. The other components need be exhaustively tested only where the designs are changed from Mariner C. As component designs are formulated and accepted a series of compatability tests will be performed leading to the subsystem qualification test. Subsystem tests will be run both as a part of the development procedure and also for qualification of the complete subsystem.

3. Follow-on

After completion of the qualification testing the remaining problem is expediting delivery and inspection of flight hardware. This involves vendor, shop and quality control liason.

2.5.3.2 Bus Payload Platform Subsystem

The Advanced Mariner flyby/bus will be aligned in a fixed attitude with respect to the sun orienting large seminconductor arrays to convert solar radiation into usable electrical energy. As a result, detection equipment used for surveying the surface of Mars cannot be rigidly fixed to the vehicle. Instead, this equipment must bemounted on a gimbaled platform so that it can be continuously reoriented to align the optical aixs of payload cameras on the planet surface.

The planetary payload platform considered for the Advanced Mariner application is a servo controlled mounting platform serving as a base for planet oriented paylod instrumentation and detection equipment.

The automatic position control system required to maintain payload orientation with respect to the planet will consist of a servo mechanism controlling rotation about each of the two gimbal platform axes. Each position control system will have a dc, drive motor, a single axis horizon sensor, a stabilizing dc tachometer, and associated drive and summing amplifiers.

The development program may be roughly subdivided into a number of broad work categories as follows:

1) Engineering,

2) Design,

3) Manufacturing, and

4) Test

1) Engineering

The establishment of system specifications is carried on during the final design phase and will consist of developing a system specification defining the requirements of the payload platform. The task will include detailed determination of requirements for smear rate, system absolute accuracy, instantaneous accuracy under camera open shutter conditions, vibration, shock, acceleration, life, mounting restrictions, gimbal motion restrictions, and the many other factors that will determine conditions restricting platform design and development.

The development of the subsystem at the beginning of the subsystem development program will be directed to blocking out the concept in more detail than considered during the initial final design. During this period control system block diagrams and conceptual drawings will be developed using the system requirements as a guide.

Synthesis of the subsystem will require application of analytical and computer techniques to determine system constants and design parameters for the gimbal position servomechanisms. During this period the major static and dynamic gains of the system will be determined for later use in developing subsystem and component specifications.

A system error budget analysis should be made to allocate permissible platform position error to the various parts of the position control systems. Most of this work will be completed with the aid of analog computer simulation of the system. The results will be used directly to establish tolerances on subsystems and components.

Subsystem specifications will be established for the two-axis gimbal system and for the servomechanisms used to position the gimbal axes. This specification will call out detailed requirements of each subsystem with particular emphasis on interface conditions between the subsystems and between the flyby/bus. The broad system static and dynamic gain relationships with permissible tolerances that were developed under the system synthesis and error budget activities will be broken down to define the performance requirements of the subsystems.

Component requirements will be established under this activity for the dc torque motor, the tachometer, horizon sensors, and other components making up the complete payload platform. These specifications will define required transfer characteristics, input and output requirements of each component with whatever mechanical, electrical, and performance detail found necessary to permit development or purchase of the components.

2) Design

The mechanical design phase of the work will include engineering consideration of gimbal design problems and mounting requirements for the components. Effect of vibration, acceleration, and shock loadings will be studied; thermal design established; and structural and spatial compatibility with the flyby/bus reviewed. A technique for lubricating sliding and rolling mechanical parts under vacuum conditions will be selected after detailed consideration of the many approaches under current study and limitations on gimbal position accuracy due to random mechanical torque effects will be analyzed.

Payload platform electronic design will encompass conceptual design of logic necessary to meet sequencing requirements as well as analysis and circuit design of voltage, summing and power amplifiers for the position control servomechanisms. Electronic units will generally be designed with completely passive elements using welded modular constructions.

Complete drawings and wiring schematics will be made to permit manufacture of mechanical and electronic parts and to record the design.

3) Manufacturing

Manufacture of mechanical and electronic components for development units will be completed in the prime contractor machine shop or in subcontractor plants as the particular requirements dictate. Accuracy requirement of the basic gimballed platform will impose many close tolerances on many of the mechanical parts requiring significant manufacturing skill.

Selection and purchase of dc torque motors, horizon sensors, amplifiers and other components in the system will involve review of hardware availability to meet specification requirements, establishment of RFQ's with competent vendors, review of vendor capability, engineering review of component requirements with vendors and finally placing purchase orders for necessary parts. Following ordering of parts, liaison with suppliers will be necessary to assure technical and schedule performance.

Planning for component, subsystem, and system test will be an important part of the basic development program. The best plan for testing each of the important parts of the system will be formed well ahead of actual test performance to provide a working guide for test design.

4) Test

Each of the system components including torque motors, amplifiers, horizon sensors, and tachometers will be individually tested for compliance with each requirement of the component specification. This testing will not only assure that each component has the proper characteristics but will set up subsequent subsystem and system testing on a firmer basis since the basic quality of each part of the system under test will have been assured.

In order to assure a logical progression of all development performance testing, components of the subsystem will be added one by one completing performance testing with each addition. As an example, the dc gimbal axis drive motor and its power drive amplifier will be tested as components and will then be combined so that tests are conducted with the power amplifier driving the motor. This approach to the testing problem will permit direct evaluation of interface problems.

Subsystem tests will be conducted with the complete subsystem to determine overall compliance with the specification. This testing should be done under a wide range of operation conditions. Subsystem testing will also include exposure to specification environments with subsequent qualification testing being performed prior to the incorporation of the platform in the system test vehicles.

2.5.3.3 Bus Communications and Power Subsystem

The communication and power subsystem will be similar to the corresponding Mariner C systems and in addition will include a relay telemetry link receiving subsystem. The transponder and rf power amplifiers, will be identical to the Mariner C design while the telemetry, command, high gain and low gain antennas, and power subsystems will be modified. The relay link subsystem will include a receiver, antenna and storage memory and will be a new design. The development program therefore will primarily be one of developing the relay link subsystem.

The development program includes the definition of subsystem requirements and follows through the various breadboard, engineering evaluation and qualification test programs leading to qualified hardware.

1) Subsystem requirements defined

Following the selection of the prime contractor a period of final design activity will take place during which the prime contractor will examine the differences between the submitted design and the design ultimately selected by JPL, and subsequently generate requirements for the various subsystem.

2) Procurement specifications and drawings

Procurement specifications and drawings are prepared from the subsystem requirements and include detailed design requirements and design boundaries, viz. maximum envelope dimensions, shape factors, maximum power consumption.

3) Bid review

Unless sole source (selected subcontractor team) procurement is allowed, a review of other proposals will take place. This will involve a technical evaluation, facility inspection and cost review for each bidder. It is assumed that final selection would require JPL approval.

4) Breadboard design and test

At subcontractor go-ahead breadboard design is started. Breadboard tests will check subsystem conformance with the design specifications and will include tests at the operating and nonoperating temperature extremes. Breadboard components will be parts determined in the preliminary design study as acceptable from reliability and other points of view.

RE-ORDER No. 64-52

The telemetry, command and other subsystems requiring modification would only require partial breadboarding.

5) Preliminary specifications and drawings

Preliminary specifications and drawings are detailed versions of those used in procurement. For example maximums used in procurement would be replaced by toleranced values, and envelope and other detailed drawings would be made. Unless design changes occur these specifications and drawings would be the final versions.

6) Engineering evaluation units

Engineering evaluation units are the first packaged versions of the breadboard designs.

The packaging techniques to withstand the launch vibration environment will have been investigated in detail during the preliminary design study, and would rely partly on techniques evolved in Mariner C. Parts layout and drawings can be started early since design changes resulting from breadboard testing will be for the most part component value changes or minor redesign effecting one or more modules. Assembly and test of the first prototype will occur late in the breadboard test phase. Packaging problems and performance changes due to proximity effects will be determined and corrected.

7) Engineering development tests

Engineering development tests include those tests conducted at the subcontractor and vendor facilities and at the prime contractor's facility. These tests would include a complete check of the engineering evaluation unit's conformance to the design specifications and performance of the unit while subjected to the critical environments expected. The evaluation will indicate any design changes required to meet the specified performance requirements during the critical environments. Also, the evaluation will in some part determine the limit of performance. Parts will be subjected to environmental conditions exceeding the design requirements in those cases which appear marginal.

8) Subsystem integration tests

Subsystem integration tests are compatability tests between major parts of the subsystem. These tests can overlap the engineering development tests since all parts will be available. Also, any changes required in development tests units as a result of these tests can be incorporated as part of the development test program.

9) Qualification test units

Qualification test units are prototype units identical to or incorporating the design changes resulting from the engineering development tests. Unless additional design flaws are uncovered in qualification testing, these units would be the production versions.

10) Qualification Tests

Qualification testing consists of monitoring the performance of qualification test units while they are subjected to simulated versions of the expected environmental conditions to be experienced by flight hardware. These tests are given in the expected environmental sequence. A qualified part is a production unit identical to a qualification test unit that met all design specifications during these tests. Qualification tests would not be required on the transponder, power amplifier and other subsystems identical to the Mariner C designs.

2.5.3.4 Bus Attitude Control Subsystem

The first task following availability of final subsystem requirements is to complete the final designs, working closely with the vendors where necessary in the following three areas:

1) Reaction control subsystem.

2) Electro-optical sensors.

3) Autopilot.

A complete list of manufactured items is shown in table 4. The completion of final design should result in the issuance of complete preliminary drawings, specifications, and work statements to the subcontractors and suppliers.

The first development hardware sets will then be manufactured and received at the prime contractor's site, where preliminary tests will be performed, starting in the third quarter of 1966. The first hardware sets will be visually inspected for workmanship and cleanliness and bench tested to see that they perform within specifications in a nominal indoor environment. The more significant of these tests are described below:

1) Solenoid valve/nozzle assembly

When exposed to the same pressure differential as in flight, examination is made of valve operation with respect to delay time, rise time, chatter, minimum allowable "on" time, and leakage.

2) Regulator

Chamber pressure is checked (to within specified tolerance) under expected combinations of flow rate and tank pressure, using nitrogen.

TABLE 4

MANUFACTURE OF ITEMS BY PRIME CONTRACTOR VENDOR

Items	Manufactured by Prime	Manufactured by Vendor
A. Reaction Control Subsystem		X
1. Nitrogen Tanks		X
2. Solenoid Valve/Nozzle Assemblies		X
3. Regulators		X
4. Squib Valves		X
5. Fill and Vent Manifolds		X
6. Pneumatic Line Assemblies	X	
B. Electro-Optical Group		
1. Canopus Star Tracker		X
2. Acquisition Sun Sensor		X
3. Limit Cycle Sun Sensor		X
C. Autopilot		
1. Autopilot Electronics	X	
2. Logic Electronics	X	
3. Gyro Package (gyros and gyro electronics)		X

RE-ORDER No. 64-525

3) Squib valve

When connected in the same circuit as used on the vehicle, a check is made that the squib will not fire when exposed to specified levels of rf radiation and leakage current and that the squibs will fire when exposed to the proper current levels. A check is also made that when the squib fires, the valve position changes from closed to open. Check for valve leakage before firing squibs.

4) Fill and vent manifold

Checked for leakage.

5) Pneumatic line assemblies

Checked for leakage.

6) Nitrogen tanks

The first four tanks are pressure tested to destruction to verify the burst pressure. This is most important for personnel safety and maintenance of the entire schedule. Since the reaction control system is a low thrust ($F = 0.01$ pound) desgin, proper valve setting is very important. This in turn requires an extremely clean cold gas system which is inspected and assembled in a class 100 clean room.

7) Gyro package

Tests for this unit are the most extensive and include;

a) Single-axis rate mode linearity/scale factor tests performed on a precision rate table.

b) Single-axis integrate mode linearity/scale factor tests performed by turning the test table through a known angle and measuring the integrator outputs.

c) Single-axis drift rate tests performed on a seismic block.

d) Loop gain determination from measuring the electronic gain (current out per voltage in) and the gyro gain (gyro degrees per test table degrees).

e) Off-nominal tests to determine the changes in gyro performance (particularly drift rate) due to changes in the power supplied to the spin motor and gyro internal temperature due to the thermostat limit cycle.

8) Autopilot electronics

The electronic gains, power requirements, the dead zone and hysteresis values for the switching amplifiers, and other pertinent performance characteristics will be measured.

9) Logic electronics

Proper operation of the switching logic will be verified, and signal threshold discrimination levels will be determined.

10) Canopus star tracker

The null offset and linearity of the output signal over the field of view will be determined by use of a simulated star source. A photometric test using a calibrated light source of the proper spectral distribution will test the maximum and minimum threshold in the tracker used for discrimination. Dynamic tests will also be performed by moving the star source at known rates.

11) Acquisition sun sensor

Testing will determine that this device generates the proper error signals for a number of random orientations and that the null offsets lie within specified value. Dynamic tests (target movement) and photometric tests will also be performed.

12) Limit cycle sun sensor

Tests will verify the field of view, linearity, and null offset for each axis. Dynamic tests (target motion) and photometric tests to verify sensitivity will also be performed.

Following evaluation of test results for this first hardware set, subsystem tests will verify that the individual items are electrically and mechanically compatible with those other items with which they interconnect.

The second and third hardware sets will then be delivered for additional testing. Environmental components or subsystems tests with emphasis on the vibration and thermal environments will be performed.

In addition, integrated ACS tests using single-axis and three-axis air bearing tables will be performed to verify overall closed-loop operation about one axis and the extent of cross coupling between the axes. Acquisition of the sun-Canopus references attitude from a random initial attitude will be verified on a three-axis air bearing table. Reorientation upon command to a desired arbitrary attitude and subsequent return to the reference attitude, using the gyro reference and a three-axis air bearing table, will also be verified. Aspects of the ACS that may require improvement should be recognized from these tests and changes incorportated into the final drawings and specifications.

The system qualification tests units will then be delivered, and the assembled vehicles will be run through several tests, including type approval tests.

2.5.3.5 Bus Propulsion Subsystem

The propulsion subsystem development and qualification covers a period of 16 months and this period is broken down into two major and four secondary phases. The major phases are development and qualification while two secondary phases are component and system tests within both major phases. The timing of these phases are shown in the propulsion development schedule, figure 20.

Preceeding the actual development is a period of approximately one to two months, during the final design phase during which the propulsion system requirements are defined from a vehicle view point. These requirements are used as the basis for the contract negotiations between the vehicle and propulsion system contractors.

Following these negotiations, there is a joint effort between the propulsion and vehicle contractors to further define the actual performance and design requirements. Out of this effort will evolve the final propulsion system design and performance specifications.

1) Component development

In conjunction with the above effort the component and system hardware fabrication is started. Some of the components can be ordered early in the fabrication cycle and others will be delayed till further design effort is completed. An attempt will be made early in the fabrication cycle to determine the components requiring a long lead time, so that their fabrication may be started early. The one item now know that would fall into this category for this program is propellant tanks. Present programs are experiencing fabrication delays with regard to tanks.

Development testing of the components can take place as soon as they have been fabricated. For the proposed system there are three primary areas of component development which will require a major testing effort. These are positive propellant expulsion, thrust chamber performance, and explosive valve performance. The other components are standard and will require only a minimum development effort.

Because the thrust chamber selected for the system is very similar to several being developed by the propulsion industry most of the development testing will be concerned with obtaining the thrust and specific impulse called for in the specification. Because the propellants selected have such a wide temperature range considerable effort will be spent determining optimum performance.

The explosive valve testing will be primarily concerned with determining reliability data as it is planned to use the same type valve used in earlier Mars flyby vehicles.

The positive propellant expulsion concept will probably require the most extensive testing. A drop tower facility for creating zero g environment will be required to determine the performance of the surface tension baffle system to be used for positive expulsion of the propellant. If development programs using this concept now proceed on schedule it is possible that the test effort might be reduced appreciably because the size tank being developed is the same as that required for the bus.

2) <u>Subsystem development</u>

As soon as sufficient components are available then the subsystem testing will get underway. The primary purpose of this is to determine subsystem performance and at the same time remove any interference effects between components. The testing will cover all the areas that will be part of the system qualification testing. This will insure the least amount of time required for qualification.

a) Component qualification

Once sufficient component development testing has been completed the component qualification will be started. The qualification will be done according to the test procedures arrived at and agreed to during the development program. The primary objective will be to show by test that the system components meet all specifications.

b) Subsystem qualification

This phase of the program is similar to that for components except that it will be done using the entire propulsion system in its flight configuration, using qualified components. This test will simulate as near as possible or exceed all launch and flight environments preceding and during flight. As with the components the test procedures and qualification specifications will be arrived at and agreed to during the development phase.

2.5.3.6 Bus Temperature Control Subsystem

Initial development work shall evaluate the fundamental thermal characteristics of the bar design.

Through analytical computations the requirements of the overall vehicle are established and the data obtained from development testing shall be compared to the analytical results.

The influence of such intangible factors as contact resistance across joints, and effects of radiating louvers, etc. can thus be studied and included in the future analysis.

The first series of high vacuum testing will, therefore, take place with a thermally true mockup model. α and ϵ values, projected to total area as well as contact resistance across joints must be correct. However, all electronic equipment can be simultaed by electric heaters which are incorporated in dummy boxes of correct mass and surface characteristics.

Time constant response as well as interaction effects can be correctly evaluated from this series. The main parameters will be: Solar intensity (Earth and Mars), "equipment" turned on or off, lander on or off, panels extended or not. In a second series, the transient response on turning maneuvers will be studied by suspending the model and rotating it slowly relative to the sun vector.

In addition to the above major parameters, the α and ϵ values of electronic boxes as well as contact resistance across attachment feet of same are also studied. By varying the intensity of the dummy heaters beyond the nominal values it is possible to study the limits of the overall system.

The influence of the plume cannot be duplicated directly but heater elements on the nozzle skirt can reproduce a realisitc temperature time history of the outside nozzle surface and thus its radiative effects on adjacent structure and equipment. The development work shall also form the basis for type approval testing. With a good knowledge of gradients and temperature levels, simplified and accurate placement of instrumentation for type approval testing is possible .

Finished vehicles with attached lander will undergo complete system testing in a high vacuum chamber with solar simulation.

Existing chambers will not have sufficient size to allow complete solar coverage of vehicle with all panels in fully extended position. However, this is not necessary as the influence of active solar panels on the system is already known.

2.5.3.7 Bus-Lander Separation System

The major development required for this subsystem is a test sequence that confirms the operating characteristics of the integrated separation system. Since the individual components are off-the-shelf, development of each item is unnecessary. However, to the extent practical within the limitations of the time schedule, it is necessary to test and review the interface outputs of the various subsystems.

A brief description of the conceptual separation system and its operating characteristics will clarify the following discussion. In broad terms the system is composed of the following:

1) Three explosive tiedown bolts and release springs.

2) Spin rockets.

3) A sterilization canister.

4) A pyrotechnic system for cutting the canister.

5) A jettison mechanism for the lander retrorocket.

6) A yo-yo despin unit.

The system sequence and operating characteristics are as follows:

1) Explosive units are actuated.

2) Three springs impact at velocity of 1 ft/sec to the lander and sterilization canister.

3) Two spin rockets spin the lander and canister up to 20 rev/min (1 second after separation).

4) The canister is split into four segments by linear shaped charges.

5) The canister segments are jettisoned centrifugally.

6) Lander retro fires.

7) The lander retor is jettisoned by a pyrotechnic spring system.

8) A yo-yo system despins the lander to near-zero rpm.

The preliminary and final design of this subsystem will be completed as part of the over-all bus mechanical design. The program is then comprised of test program and sequence design; design, procurement and set up of test stands and fixtures; functional development testing; test result evaluation, final design configuration; testing, and qualification testing.

Although the time schedule precludes a flight test of a prototype, the test schedule has been planned so as to simulate as large a fraction of the over-all separation sequence as is practical with ground facilities and under nonzero g conditions. As is called out in the schedule in figure 21, the functional development test program has seven phases: pyrotechnic sterilization, separation mechanism, spin rockets, sterilization can jettison, lander retrorocket jettison, and yo-yo despin release.

In addition, qualification testing will be carried out concurrently with the function testing and continued until the end of the first quarter of 1967. These tests are briefly described in the following paragraphs.

1) Pyrotechnic sterilization

Candidate explosive devices and linear shaped charges will be subjected to the sterilization cycle. Performance will be evaluated before and after cycling in the heat environment.

2) Separation mechanism

The objective of this test will be to confirm and possibly modify the preliminary design concept into a reliable tiedown and release system. It will be completed in three phases. Phase I will consist of conceptual design and development tests to determine feasible concepts and demonstrate the operation of prototype single tiedown mechanisms.

Phase II will commence after selection of a reference design. It will begin with tests of single tiedown mechanisms and end with a successful test of a three-point tiedown mechanism representative of the final design, but manufactured from prereleased drawings.

Phase III will be a test for a complete three-point mechanism. The test will be conducted in conjunction with a sterilization can jettison test. This approach simplifies test procedures and provides a minimum of separate test articles at this level of development demonstration testing.

3) Spin rockets

This development task would be accomplished in two phases. (It should be noted that design and procurement of the spin rocket is considered as part of the lander propulsion task.) Phase I would be a structural test evaluation of the bracketry used to attach the spin rocket motor to the sterilization canister.

Phase II would be a demonstration test of the spin-up capability of the system utilizing a sterilization canister and lander vehicle mass simulation. The sterilization canister would be the same article as that used for demonstration test of the sterilization canister jettison test.

4) Sterilization can jettison

Development testing of this action will be completed in three phases. In the first phase conceptual design development will be performed to determine the required grain loading of the flexible linear shaped charge (FLSC), FLSC initiation system, and FLSC back-blast holder. This phase shall utilize only linear representations of the evolving design.

Completion of Phase I tests and evaluation of a reference design will be followed by Phase II tests. These tests will initially utilize additional linear samples. They will be completed upon successful demonstration of a jettison test of a full sterilization canister manufactured to prerelease drawings.

In Phase II an effort will be a functional demonstration test of a sterilization canister jettison system manufactured to release drawings. The test article shall be used prior to the test described herein for demonstration test of the tiedown release system.

5) Lander retrorocket jettison

Phase I of this test will consist of conceptual design/development studies to evolve the jettison system design. These tests shall consider the sterilization requirements of the various explosive components of the jettison system.

Phase II will provide for the structural evaluation of the rocket motor/lander attachment hardware. Tests shall consist of loading tests under pertinent thermal conditions.

Phase III testing will consist of functional demonstration tests of the jettison system manufactured to release drawings. Three tests are anticipated.

RE-ORDER No. 64-525

6) Yo-yo despin system release

During the first phase of this test the conceptual preliminary design release mechanism will be constructed and tested with sequential modifications in the design to achieve the design objectives. These tests will utilize representative single, weight release devices.

In the second phase the final design will be subjected to functional demonstration tests utilizing hardware manufactured to release drawings. Fixtures representative of the lander in details essential to the function of the despin system will be used in these tests. The fixtures will provide the capability to accurately achieve rotational speeds consistent with the flight environment. Four tests at this level are considered sufficient to demonstrate the design requirement compliance.

2.5.3.8 Scientific Liaison - Bus and Lander

During the development and manufacture of the Advanced Mariner spacecraft, it is anticipated that the individual scientific instruments will be under development and construction by separate teams of experimenters. In order that each instrument should finally be totally integrated into the design, test and operation of the spacecraft, considerable liaison must be maintained between NASA, the vehicle contractor, and each of the scientific instrument teams.

As part of the development portion of the overall program, intensive consideration must be given to the interactions between the operational aspects of the experiments and the total system, as for example, the location of the magnetometer on the vehicle. For these questions, scientifically trained contractor personnel must be fully cognizant of the problems and requirements of each scientific experiment.

During the manufacture and test phases of the program, the engineering requirements imposed on the instrumentation must be coordinated with the instrument manufacturer. For this work, the contractor must supply instrumentation specialists with broad knowledge and experience in flight instrumentation. In addition, he will perform the necessary function of translating instrument requirements into design specifications on the spacecraft and test procedures.

During the course of this liaison effort, considerable travel will be required because the experimenters will be working at many locations across the country. It is estimated that a minimum of one visit to each of possibly ten experimenter groups will be required each month.

RE-ORDER No. 64-525

2.5.3.9 Lander Aerodynamics

For the selected mission and design concept, it will be necessary to determine the aerodynamic coefficients, entry trajectories, heating and pressure distributions, etc., in the preliminary design study. The complete range of possible Martian atmospheres will be considered.

The preliminary design will be a function of the size, weight, and packaging of the scientific equipment, the descent and impact attenuation systems, and the minimum static margin determined in the preliminary design for the entry conditions under consideration.

When the preliminary and final designs have been completed, a wind tunnel test program (at JPL or NASA) will be conducted to confirm the aerodynamic characteristics as a function of Mach number, angle of attack, Reynold's number, and atmospheric composition.

Trajectory analyses will be performed by means of four-degree and six-degree-of-freedom computer programs, using the experimentally determined coefficients and the current best atmospheric data.

A test program will be conducted to confirm the theoretically determined pressure and heating distributions. A heating evaluation will then be performed utilizing test data and the heating pulses computed in the trajectory analysis.

Concurrent with the lander vehicle development and dependent upon its final design and entry characteristics, a method of determining the Martian atmosphere with on-board instrumentation will be developed.

2.5.3.10 Lander Communications and Power Subsystem

The communication and power systems will be new designs and will require extensive design and development to survive the dry-heat sterilization and impact shock environments. The most critical development items expected are the 90-watt rf power amplifier and pre-entry antenna. The 90-watt amplifier is a development model based on an extensively tested 20-watt device. The pre-entry antenna design is affected by the heat shield material selected, therefore, the final design is contingent upon the heat shield studies.

The development program includes the definition of subsystem requirements and follows through the various breadboard, engineering evaluation, and qualification test programs to finally arrive at qualified hardware.

1) Subsystem requirements defined

Following the selection of the prime contractor a period of final design activity will take place during which the prime contractor will examine the differences between the submitted design and the design ultimately selected by JPL and subsequently generate requirements for the various subsystems.

2) Procurement specifications and drawings

Procurement specifications and drawings are prepared from the subsystem requirements, and include detailed design requirements and design boundaries, viz. maximum envelope dimensions, shape factors, maximum power consumption.

3) Bid review

Unless sole source (selected subcontractor team) procurement is allowed, a review of other proposals will involve a technical evaluation, facility inspection and cost review for each bidder. It is assumed that final selection would require JPL approval.

4) Breadboard design and test

At subcontractor go-ahead breadboard design is started. Breadboard tests will check subsystem conformance with the design specifications and will include tests at the operating and nonoperating temperature extremes before and after applications of sterilization heating environment. Breadboard components will be parts determined in the preliminary design study as acceptable from the sterilization temperature, reliability, and other points of view.

The programmer, exciter, power amplifier power supply, power switching and logic, telemetry, and core memory subsystems would require complete or partial breadboarding.

5) Preliminary specifications and drawings

Preliminary specifications and drawings are detailed versions of those used in procurement. For example maximums used in procurement would be replaced by toleranced values, and envelope and other detailed drawings would be made. Unless design changes occur these specifications and drawings would be the final versions.

6) Engineering evaluation units

Engineering evaluation units are the first packaged versions of the breadboard design.

The packaging techniques to withstand the impact shock and vibration environments will have been investigated in detail during the preliminary design study. In most cases, viz. battery, core memory, the castings, or other case designs will be determined early allowing their manufacture before the end of the breadboard design and test phase. Parts layout and drawings can also be started early, since design changes resulting from breadboard testing will be, for the most part, component value changes or minor redesign effecting one or more modules. Assembly and test of the first prototype will occur late in the breadboard test phase. Packaging problems and performance changes due to proximity effects will be determined and corrected.

7) Engineering development tests

Engineering development tests include those tests conducted at the subcontractor and vendor facilities and at the prime contractor's facility. These tests would include a complete check of the engineering evaluation unit's conformance to the design specifications and performance of the unit while subjected to the critical environments expected. Typically, these include the sterilization temperature, impact shock and entry, and launch vibration environments. The objective of the engineering evaluation is twofold. First, and most importantly, the evaluation will indicate any major design changes required to meet the specified performance requirements during the critical environments. Secondly, the evaluation will in some part determine the limit of performance. Parts will be subjected to environmental conditions exceeding the design requirements in those cases which appear marginal.

8) Subsystem integration tests

Subsystem integration tests are compatibility tests between major parts of the subsystem. These tests can overlap the engineering development tests since all parts will be available. Also, any changes required in development test units as a result of these tests can be incorporated as part of the development test program.

9) Sterilization unit

Sterilization tests are performed on prototype units which may or may not have been qualification tested. Although the qualification tests may reveal flaws requiring minor redesign the changes will not affect the sterilization unit since sterilizeable parts will be used and the sterilization test is a nonoperating environment. Operational tests will be performed before and after the heat sterilization cycle.

10) Qualification tests units

Qualification test units are prototype units identical to or incorporating the design changes resulting from the engineering development tests. Unless additional design flaws are uncovered in qualification testing, these units would be the production versions.

11) Qualification tests

Qualification testing consists of monitoring the performance of qualification test units while they are subjected to simulated versions of the expected environmental conditions to be experienced by flight hardware. These tests are given in the expected environmental sequence. A qualified part is a production unit identical to a qualification test unit that met all design specifications during these tests.

2.5.3.11 Lander Structure Subsystem

1) Design analysis

The Advance Mariner lander must be analyzed to establish that the structural design will maintain its integrity under the loadings to which it will be subjected in the various environments. The evolution of the design requires the establishment of the envrionments, loads, design criteria, and an investigation of all of the possible modes of failure for the critical loading conditions.

The environments that must be defined consist of entry, interplanetary transit, ascent, and preflight. From these environments the critical loading and temperature conditions will be ascertained and design criteria will be determined to insure structural integrity.

The analyses will consist of elastic stability considerations of the honeycomb front cap, involving both general and local instability requirements. The afterbody must also be examined for instability. A stress analysis must be performed for all of the shell elements of the lander. The analysis will be done for both symmetric and unsymmetric loading distributions and will include the effects of line and point loads.

Thermal structural studies must be conducted to assure integrity of both heat shield and substructure composites and overall vehicle compatibility. Composite structural design of the 5026 heat shield with aluminum honeycomb must be analyzed for thermal compatibility. The entire vehicle structure must then be examined for interaction of thermal discontinuities.

The internal structure, subject to local loadings, must be examined. The tiedown mechanisms and bus interface must be analyzed for the conditions of separation and shock loadings. The sterilization canister must be analyzed for its stability and separation characteristics. Special detail analysis must also be given to numerous local cutouts in the spherical cap and afterbody and to junctions between shell and support sections. Finally, the overall vehicle must be examined under both thermal, intertial, and pressure loadings to assure overall vehicle integrity.

A dynamic analysis must be performed on a lander structure for the ascent environments, for the determination of component response and for transmitted loads. The analysis will be supplemented by a test program using a basic structure with dummy components attached. The acoustic environments for ascent and entry will be examined in greater depth to assess the impact of these environments on the structural design. The lander must also be analyzed for the rigid body dynamics at separation. The ground handling environment must be examined in order to determine the loads transmitted to the lander.

2) <u>Development tests</u>

The following tests will be performed to verify the structural concept of the lander.

a) Model tests

Full scale spherical sandwich shells will be subjected to symmetric and unsymmetric pressure loadings to examine the behavior of the shell. These shells, will not have any of the cutouts or structural rings necessary in the actual shell configuration, although the shell undergoing unsymmetric loadings will be mounted with the proposed toroidal sections. The symmetric and unsymmetric pressure loadings will be simulated by pressurizing the shell through an arrangement of baffles having different pressure levels. The resulting stress distributions in the shell and toroidal section, when applicable, due to these pressure loadings will be measured by attached strain gages.

b) Static tests

Full scale spherical sandwich shells, including the cutouts and structural rings will be subjected to the same tests as the models previously described. The buckling behavior of the shell will be examined for the symmetrically loaded shell and stress distributions in shell and toroidal section will be examined for the unsymmetrically loaded shell.

A full scale beryllium afterbody will be subjected to pressure and axial loadings to examine the behavior of the monocoque shell. The test fixtures for these tests are readily available.

c) Dynamic tests

A full size lander structure with simulated components will be subjected to a vibration excitation and the response of the simulated components measured. This frequency of excitation and g loadings will be determined by ascent environment. For the proposed lander weight and vibration levels, it is not expected that there will be any problem in conducting this test.

d) Thermal structural tests

The same lander structure used in the dynamic tests will be subjected to two thermal soak conditions. These soak conditions will involve a hot and cold soak simulating the deep space and sterilization environments. The lander will also be subjected to quartz lamp heating and simulate entry gradients.

Thermal studies will be performed on test pieces of composite materials structures. The material combination which will be subjected to both "hot" and "cold" environments are aluminum honeycomb with heat shield material facilities required for these thermal tests are available at most large space contractors.

2.5.3.12 Lander Thermodynamics and Materials

1) <u>Thermodynamics</u>

a) Design analysis

The heat shield of a lander entering the atmosphere of Mars is very dependent on the size and shape of lander, atmospheric model, and entry conditions. These variables define the heating load and consequently, along with the material selection and entry time the heat shield design may be defined.

During the preliminary design phase when the majority of the above parameters are being defined a materials evaluation program should be conducted around a reference heat shield material selection. The evaluation should develop the most optimum thermo-physical properties that best satisfy the lander mission and compatibility with the substructure design.

Computer programs should be developed (or existing programs modified) to handle the effects of the Martian atmosphere model and the uncertainties in material behavior. Analysis employing consistent thermo-models will be performed using these programs by combining both radiative and convective heating loads to establish the required heat shield design. Thermo-physical properties generated in the test program will supplement the design analysis. Compatibility of the heat shield design with the space and sterilization environments should be projected into all phases of the heat shield design.

All studies of the lander afterbody heat shield designs have indicated that a thin skin beryllium heat sink design produces the optimum weight. The thermodynamic analysis should therefore be based entirely around this type of a design. Two dimensional heat transfer analyses should be performed considering all combination of entry conditions to fully evaluate the compatibility with the structural integrity of the external and internal configuration. The effects of reradiation both to space and to the payload package along with the effects of thermal control coatings and insulation are typical problem areas subject to analysis.

b) Test program

The thermodynamic test program as outlined in table 5 is designed to yield the required amount and type of material thermal behavior information necessary for the capsule heat protection system design.

One basic heat shield material can be tested to obtain thermal performance design information. The tests proposed will supplement and extend this information for Mars type atmospheres and anticipated combined convective and radiant heating environments.

RE-ORDER No. 64-525

TABLE 5

THERMODYNAMIC TEST PROGRAM

Type of Test	Test Facility	Material	Test Conditions	No. of Tests	Objectives
A. Environmental Definition 1. Laminar Convective Heating a. Low Shear b. High shear	Arc;Cornell Type Superheater	Pressure probe and calorimeter	3 atm at 5 conditions 1 atm at 5 conditions	15 5	Pressure profile heat flux profile enthalpy level
2. Radiant Heating	Solar furnace and Arc imaging furnace	Pyrometer calorimeter radiometer	5-3000 But/ft^2 sec	8 8	Heat flux level spectral and spatial distribution of intensity
3. Combined Convective	Arc with radiation capability	Pressure probe calorimeter radiometer spectrometer pyrometer	3 atm at 3 convective rates x 3 radiant rates 27 tests/ facility	27 27	Radiant source spectral and spatial distribution, pressure profile, convective and radiant flux profile, mirror system efficiency
B. Material Behavior 1. Convective Heating a. Low shear b. High shear	Arc, and Cornell Type Superheater	Heat shield specimen	3 atm at 6 tests/material 1 atm at 5 cond. at 2 tests/ mat'l	18 10	Separate combustion heating, obtain surface temp. and emissivity, observe char retention w/high shear, obtain temp. profiles and surface recession rates.
2. Radiant Heating	Solar Furnace, Arc imaging furnace	Heat shield specimen	3 heating rates	9 9	Char density and composition, surface recession rate, surface temperature
3. Combined Convective Radiant Heating	Arc with radiation capability	Heat shield specimen	3 atm at 3 radiant-convective ratios at 3 radiant rates at 3 enthalpy levels 81 tests for prime materials	81 81	Surface recession rate, char depth, heat of ablation temp. profiles
4. Laboratory Pyrolysis	Convective and radiant furnaces	Heat shield specimen	3 Heating rates at 2 furnaces at 2 atm 12 tests/ mat'l.	12	Vapor products identification, char composition
C. Thermal Model Proof Tests 1. Combined Convective-radiant heating	Arc	Heat shield specimen	3 radiant-convective rates at 2 enthalpy levels at 2 test/material	12	Check validity of analytical prediction methods with experimental mass loss, char growth and temp. gradient histories from instrumented models.
D. Basic Properties	Materials lab.	Heat shield specimen	TGA, K, P, C_p	12	Establish basic properties for exact mat'l formulation used
E. Heat Shield Structure Interface Tests 1. Structure effectiveness 2. Effect of holes and joints 3. Antenna window behavior	Arc and Quartz lamp heating facility	4 heat shield mock up sections	3 heating rates	12	To determine bond structure effectiveness and validity of predictions.
F. Thermal Control Coating effect on Heat Shield	Arc	Heat shield specimen	3 enthalpy levels	3	To determine the thermal control coating effect on material ablation
G. Thermal Control Coating Afterbody heating	Quartz lamp heating facility	3 afterbody structure samples	3 heating rates	9	To determine the effect of thermal control coatings on afterbody structure reradiation characteristics.

Laminar convective heating tests can be used to determine heats of ablation, temperature distributions, and combustion heating rates. The magnitude of the combustion heating in Mars type atmospheres will be obtained by the use of splash-type tests in inert and active atmospheres. Temperature profile will be obtained by use of imbedded thermocouples. Preliminary tests by this contractor have shown material heats of ablation to be higher in the Mars type atmosphere than in the combustion supporting earth atmosphere.

High level pure radiant heating can be simulated by use of a solar furnace or arc imaging furnace. Chars formed from pure radiant heating should be evaluated for density, depth, and pore size. Temperature gradients and surface recession should be measured also.

Aerodynamic simulation with combined convective radiant heating in 3 atmospheres should be carried out. Using the combustion results from pure convective heating in inert and active atmospheres, a heat of ablation can be experimentally determined for materials subjected to specific convective - radiant heating ratios. Four heat transfer mechanisms must be considered for the Mars entry: 1) convective 2) combustion 3) incident radiation 4) reradiation Laboratory pyrolysis will attempt to identify ablation products and char composition for varied heating rates and atmospheres.

Thermal model proof tests and heat shield - structure interface tests are included to obtain compatibility assurance between design prediction and experimental performance.

2) <u>Materials</u>

a) Heat shield development

The heat shield material on the forebody (blunt end) of the lander which is referenced in the conceptual design is considered here. The fabrication of a very thin heat shield and any new material orientations will be evaluated by limited mechanical, thermal, and ablation testing. To sublimate the engineering design and analysis extensive testing will be conducted on small specimen level for thermo-physical properties. This testing shall include effects due to all the environments (i. e., sterilization, space vacuum and temperatures entry heating and etc.) to which the lander will be subjected. Other specimens will be furnished to the thermodynamics and structures development program for evaluations.

The reference heat shield design for the afterbody (30 degree conical section) will be a thin skin beryllium shell. Many problems associated with beryllium as a thermo-structural material have been overcome in recent design developments (namely for the Minuteman missile). However, the Advanced Mariner lander will be subjected to very adverse environments which will require that this material be thoroughly evaluated for the thermo-structural physical properties necessary for the design analysis. Both elemental and full-scale tests will be required. Samples will be cut from test afterbody sections and evaluated for typical thermo-structural properties at temperatures ranging from 500° to 1500°F. Structure integrity will be investigated on a full scaled afterbody section under both hot and cold soak environments. Where high discontinuties exist as the the results of these tests better fabrication techniques and material properties will be found and proposed.

b) Thermal control coatings

Thermal control coating will be applied to both this heat shield and the beryllium afterbody. Typical primary materials are vapor deposited aluminum and paints. A sealant coating must be applied to the heat shield to provide a smooth surface. These sealants are of the nature already developed for the Apollo program. Studies will be conducted on thermal control coatings to furnish the most desirable coating in terms of required properties and compatibility with the substrate. These studies will include the effects of surface finish on the substrate uniformity of thickness, bond strength, and ease of fabrication. Optical properties will be measured after exposure for various lengths of time to simulated space environments, including high vacuum, ultra-violet irradiations, proton bombardment, micrometeorite impact and extreme temperature cycling.

c) Seals, joints and insulators

A number of material interfaces exist on the lander. These interfaces must fulfill several design functions, such as, a sealer, insulator and load carrying member. One typical interface would be the heat shield/aluminum-beryllium junction. At this point the interface must be capable of withstanding high temperature gradients pressure loads and thermo stresses. Several silicone sealants and insulators have been developed for such programs as Apollo and can be employed here.

d) Sterilization

All materials on the vehicle willbe sterilized according to current NASA specifications. Each material will be exposed to the prescribed sterilization cycle and evaluated for mechanical and thermal properties, structural integrity, optical properties and dielectric properties. Any changes in material properties will be defined and the effect on vehicle performance thoroughly evaluated.

2.5.3.13 Parachute Subsystem

The major categories for the parachute development plan are Engineering Analysis, Subsystem Design, Development Testing, and Qualification Testing, each of which is discussed below.

1) Engineering analysis

Engineering analysis for the development program should include aerodynamic stability, aero-thermodynamic and dynamic loading analyses of the drogue, and the main parachute assemblies. The actuation system and sequence controller analyses should also be carried out.

2) Subsystem design

The parachute subsystem is composed of three basic elements, all of which are designed during this development program:

a) Drogue parachute, which includes drogue parachute sizing, material, risers, etc., drogue mortar assembly, and integration of the dorgue parachute into the vehicle design.

b) Main parachute, including main parachute, deployment bag, riser, and disconnect system, and integration of main parachute into vehicle design.

c) Actuation and sequencing system, including safing and arming sequence, and electrical, mechanical, pyrotechnic elements.

3) Development testing

The requirements for development test hardware, component testing, and subsystem testing are outlined below.

a) Test Hardware requirements include Wind tunnel models for vehicle-drogue and main parachute combinations for drag, stability, and optimum riser length determination; G-switch/timer switch drogue and main parachute deployment initiations units, including the drogue mortar assembly; Rocket boost vehicles for high Mach number drogue parachute testing, including the following:

1 Determination of required test program for best Mars entry simulation.

2 Selection of booster configuration to achieve test ponts.

3 Design of test vehicle to carry experimental drogue chute system; and finally Aerial drop test vehicle to include prototype drogue and main parachute systems with deployment initiation systems.

b) Component Test requirements include Sterilization heat cycling tests on nylon and HT-1 and pyrotechnic and actuation devices. For nylon the effect of the required sterilization heat will be tested with an inert atmosphere on both materials samples and full- or scale-model chute packs.

They also include long-term vacuum testing of nylon and HT-1. Complete packed chute testing desired. Minimum test time is 30 days. Equipment required: 4 x 4 x 4 foot test space, high vacuum chamber with large ($S_p \leq 10^5$ liters/sec) pumping capacity at 10^{-6} torr. Ultimate vacuum of chamber to be in the range of 10^{-8} torr. Also facility for solar heating of the test specimen during vacuum test is desirable. Following removal of test chute from pack after vacuum testing, physical testing of fabric should take place to determine its post-flight characteristics.

The third component test requirement is acceleration testing of g switch timer drogue chute deployment initiation controller, up to a limit of 10 g.

c) Subsystem testing requirements include Wind tunnel testing of vehicle - parachute configurations -- 12 to 15 tests at the Mach number range of 0.5 to 4.5; Aerial drop tests of prototype subsystems with boiler plate vehicle. Drops will test drogue chute deployment, including mortar operation, drogue-vehicle stability, drogue chute drag, main chute deployment, opening and final disconnect after impact. Number of vehicles-2, number of drops - 12.

The third subsystem test requirement is for rocket booster vehicle tests of drogue deployment and deceleration at high Mach numbers to determine drogue deployment operations, and drogue-vehicle stability. Number of tests - 6, and number of vehicles -6. Test point range: 75,000 feet altitude and Mach 1.8 to 125,000 feet altitude and Mach 4.0.

For the subsystem tests instrumentation which is presently contained in the CREE vehicle would be adaptable. This instrumentation allows for in-flight source measurements and in-flight photographic coverage. For these tests standard solid boosters could be used to obtain the desired performance levels. In this series of flights, trajectories would be flown to simulate drogue deployment conditions. To obtain these values, trajectory flight paths would be chosen so that the desired parameters could be obtained.

4) Qualification testing

Qualification testing will be carried out in order to insure the operability of the developed hardware after having been subjected to all the anticipated environments. Environmental testing should include the following:

a) Sterilization.

b) High vacuum - solar heating.

c) Shock.

d) Vibration.

e) Flight operation.

The items to be subjected to the above environmental tests are the following:

a) Actuation devices.

b) Pyrotechnic devices.

c) Drogue mortar assembly.

d) Drogue parachute pack - canopy, lines, etc.

e) Main parachute pack - canopy, lines, etc.

2.5.3.14 Impact Attentuation Subsystem

The development plan for the impact attenuation system includes detailed testing of materials and studies of fabrications methods.

The test program is divided into materials tests and configuration tests. The material tests objectives are to supply data for the analysis and design of the impact attenuation system and to evaluate the applicability of various materials to the system (e.g., bonding agents, etc.). To this end the materials testing program concerns itself with small-scale static and dynamic tests on the crushing strengths of specimens at various orientations (an important effect in an anisotropic material like aluminum honeycomb), strain rates, temperatures, and in various geometries. Further, environmental tests would be performed to assure the usability of materials during or after exposure to sterilization, cold soak, radiation, and vibration.

The configuration test objectives are to prove out the design of the impact attenuator in its full-scale spherical segment geometry and to provide data to serve as criteria for the internal payload. Both well controlled, well instrumented tests using rocket powered sleds and proof-type tests involving drops of complete assemblies from aircraft onto various terrains are included in this category.

Studies of fabrication techniques ranging from the method of joining the honeycomb foils to the methods of laying up and assembling the final spherical segments will be carried on with the test program.

2.5.3.15 Lander Propulsion Subsystem

The propulsion development and qualification covers a period of 14 months and this period is broken down into 2 major phases, development and qualification. The timing of these phases is shown in the propulsion development plan, figure 30.

Preceeding the actual development is a period of approximately one to two months during the final design phase during which the propulsion system requirements are defined from a lander viewpoint. These requirements are used as the basis for the contract negotiations between the vehicle and propulsion system contractors.

Following the negotiations there is a joint effort between the propulsion and vehicle contractors to define further the actual performance and design requirements. Out of this effort will evolve the final propulsion system specifications.

1) <u>Development</u>

The fact that the propulsion system selected is a solid propellant engine with modifications to a standard engine means that the development effort will not be extensive. Basically the development testing will concern itself with the proving out of the modifications to the basic engine.

There is one exception to the above statement and that is in the area of engine sterilization. The sterilization requirement is such that the engine has to withstand without performance degradation a 135°C temperature soak period before launch. To date no complete engine has gone through such a test, but because of associated work and some testing of propellants at the required temperature no major difficulty is expected. Therefore, the tests in this area will be to assure that the entire assembly will withstand the sterilization environment.

2) Qualification

Once sufficient development testing has been completed the engine qualification will be started. The qualification will be done according to the test procedures arrived at and agreed to during the development program. The primary objective will be to show by test that the engine meets all specifications. The test will simulate as near as possible or exceed all launch and flight environments preceeding and during flight.

2.5.3.16 Lander Thermal Control Subsystem

Initial development work shall evaluate the fundamental thermal characteristics of the lander design. The requirements of the thermal control system are established by analytical testing, then later compared with data obtained from development testing. The influence of factors such as contract resistance across joints, and insulating characteristics of heat shield and backface material can thereby be measured.

The first series of high vacuum testing will, therefore, take place with a thermally true mockup model. α and ϵ values, projected to total area as well as contact resistance across joints must be correct. However, all electronic equipment can be simulated by electric heaters which are incorporated in dummy boxes of correct mass and surface characteristics.

Time constant response as well as interaction effects can be correctly evaluated from this series. The main parameters will be: Solar intensity (Earth and Mars), and "equipment" turned on or off.

In addition to the above major parameters the α and ϵ values of electronic boxes as well as contact resistance across attachment feet of same are also studied. By varying the intensity of the dummy heaters beyond the nominal values it is possible to study the limits of the overall system.

The development work shall also form the basis for type approval testing. With a good knowledge of gradients and temperature levels, simplified and accurate placement of instrumentation for type approval testing is possible.

Finished vehicles with attached bus will undergo complete system testing in a high vacuum chamber with solar simulation.

Existing chambers will not have sufficient size to allow complete solar coverage of the assembled vehicle with all solar panels in fully extended position. However, this is not necessary as the influence of active solar panels on the system is already known.

2.5.4 Ground Support Equipment

2.5.4.1 Electrical

The requirements for electrical ground support equipment (EGSE) needed to support the bus and lander of the Advanced Mariner program are indicated in the lists below.

EGSE is required to test the following lander components:

Data and power handling equipment.
Power amplifier and converter.
Exciter.
Antenna and waveguide.
Batteries.
Engineering instruments.
Scientific instruments.
Pyrotechnics and rockets.
Safing and initiation components.
Cabling.

It is required to test the following bus components:

Data automation system.
Central computer and sequencer.
Telemetry subsystem.
S-Band transponder.
S-Band power amplifier and converter.
Command subsystem.
VHF receiver.
TV tape recorder.
Relay tape recorder.
Antennas: omni, hemi-omni, high gain, and helix.
Batteries.
Solar cells.
Power handling equipment.
Electro-optical sensors.
Rate integrating gyros and electronics.
Autopilot electronics.

Reaction control system.
Scientific instruments.
Engineering instruments.
Pyrotechnics and rockets.
Safing and initiation components.
Cables.

It is required to test the lander and bus components in various stages of assembly and after final assembly; to test the lander-bus interface prior to mating of the lander to the bus; and to test the completely assembled spacecraft prior to its mating to the booster. Portable EGSE is required to test the spacecraft-booster interface prior to mating of the spacecraft to the booster, and blockhouse EGSE is required to check out and monitor the mated spacecraft after mating but before launch.

The tests required on components, subsystems, systems, and for preflight activities are briefly discussed below:

Equipment will be needed by quality control during acceptance tests and during various in-house proof tests. The landed EGSE will be located and used in class 10,000 clean rooms. Whenever possible existing test equipment should be used to support the components. If the required equipment is not already available, commercial test equipment may be procured and mounted in suitable racks with associated equipment. In those cases where the equipment is neither on-hand nor commercially available, it should either be designed by the prime contractor or subcontracted to a vendor. A matrix of the EGSE required to support bus and lander components is given in table 6. A description of the test sets is given in following paragraphs.

1) Inertial test set

An inertial test set will be provided to support equipment that is associated with inertial components. Equipment that will be tested by the test set includes the reaction control system, the autopilot electronics, the gyroscopes, and the associated electronics. The test set will be used in conjunction with associated handling and test fixtures.

2) Digital test set

A digital test set will be provided to support equipment that is essentially digital in nature. Equipment that will be tested by the set includes the data handling equipment, data automation equipment, and telemetry equipment. Included in the test set will be an oscilloscope, a digital counter, a digital voltmeter, a power supply, and a signal simulator. The test set will be suitable for use in the factory, field, and blockhouse.

3) RF test set

An RF test set, consisting of rack mounted microwave test equipment, will perform tests on all RF components within the bus and lander. Equipment included in the test set will be able to test the RF equipment as components and assemblies. It can also be used to check the RF equipment in the assembled lander and bus in the factory, field, and blockhouse in conjunction with other test sets.

4) Power test set

A power test set will be provided to support equipment such as batteries, power handling equipment, and solar cells. The test set will be used with associated handling, test fixtures and systems, as follows:

a) Subsystems

Test equipment will be required to check the electrical and electronic circuits within bus and lander assemblies during acceptance tests, various proof tests, and during bus and lander assembly. Whenever possible, the rf test set, the digital test set, the power test set, and the inertial test set will be used to check the performance of the assemblies. A systems test set will be provided that will include any additional equipment required during assembly tests as well as include any control equipment required to coordinate test activities. In addition to being suitable for use during assembly tests, the systems test set will be suitable for use during checks in the factory, field, and blockhouse.

b) Assembled bus and lander system

EGSE that is capable of demonstrating that the bus and lander can reliably perform their essential functions will be provided to the following test areas:

Acceptance Test Area - factory.
Proof Test Areas.
Spacecraft assembly Facility.
Acceptance Test Area - AMR.

RE-ORDER No. 64-525.

TABLE 6

MATRIX -- EGSE VERSUS COMPONENTS

	Power Test Set	Vendor Supplied	Digital Test Set	RF Test Set	Inertial Test Set	Avail. Equip.
Data Handling and Automation			X			
Power Amplifiers and Converters				X		
Exciters				X		
Antennas and Waveguides						X
Telemetry (Less RF)			X			
Transponder				X		
Tape Recorders		X				
Power Handling Eqpt.	X					
Batteries	X					
Solar Cells	X					
Scientific Instruments		X				
Engineering Instruments		X				
Pyrotechnics and Rockets						X
Safing and Initiation Components						X
Cables						X
Reaction Control System					X	
Autopilot Electronics					X	
Gyros and Electronics					X	
Electro-Optical Sensors						X
Antennas						X
Central Computer and Sequencer		X				

In the factory acceptance test area functional tests will be performed on both the bus and the lander. Tests will be performed on the lander both before and after it is sealed in the sterilization canister. Checks will again be performed on the sealed lander after sterilization.

In the proof test areas functional checks will be performed on the bus and lander at various times during the approval cycle.

All test sets being shipped to the spacecraft assembly facility AMR and to the blockhouse will be subjected to various transportation environments to provide assurance that the equipment is structurally sound.

One set of EGSE will suffice for each flight article for both the spacecraft assembly facility and for the AMR acceptance test facility. At the conclusion of the tests conducted at the SAF, all EGSE will be transported to AMR.

c) Premate tests

Interface test equipment will be provided both to the SAF and to ARM for providing assurance that the lander can be safely mated to the bus. It will also be capable of providing assurance that the bus can be safely mated to the booster.

d) Preflight tests

The RF test set, digital test set, and systems test will be provided to support the space vehicle subsequent to its mating to the booster.

The schedule shown in figure 36 indicates the general relationships of the major activities in the program of developing both the EGSE and the MGSE, which is discussed in the next section below.

While the design is largely accomplished as early in the program as possible based on the subsystem and system requirements, the design phase continues almost to the point of system equipment availability to account for the possibility of design changes.

Ground support equipment for components and subsystems is required before that for systems and is shown as being available shortly after the start of procurement in the case of off-the-shelf items and as being available just prior to the start of system testing in 1967.

Systems GSE is actually composed partly of subsystem GSE units as described above, but those units which pertain only to systems handling checkout and test will be available for use during the systems testing activities in 1967.

All of this GSE after being used during the system testing activities, is used again for the same purposes on the flight vehicles, both at the SAF and at the launch site.

2.5.4.2 Mechanical

The handling concept for the Advanced Mariner bus and lander will consist of a key handling pallet for each vehicle. The pallets will be affixed to each structure at the start of their assembly cycle and remain with each vehicle until mating operations are performed at the factory and the field. The key handling pallets will be the major interface between flight hardware and support equipment. Slings, containers, transport equipment, and test fixtures will all mate with the pallets.

The mechanical equipment currently anticipated as necessary to support the Advanced Mariner is as follows:

1) Bus

Handling Pallet
Assembly Dolly
Solar Panel Support Fixture
Transporter Stand
Protective Cover
MI and CG Adapter
Shipping Container, Solar Panels
Shipping Container, Batteries
Shipping Container, Structure
Shipping Container, ACS
Mating Kit Bus to Booster
Sling, Bus Science Package
Sling, Communication Package
Sling, Power Supply
Sling, ACS
Sling, Propellant
Sling, Structure and Pallet
Sling, Solar Panels
Sling, Mating Bus to Booster
Calibration Slug, MI Machine
Shipping Container, MI and CG Adapter
Shipping Container, Electrical GSE
Solar Panel Assembly Fixture
Pressurization and Checkout Kit

2) Lander

Handling Pallet
Assembly Dolly
Protective Cover
MI and CG Adapter
Shipping Container
Mating Kit Lander to Bus
Sling, Lander and Pallet
Sling, Mating Lander to Bus
Installation Guide, Lander to Bus
Calibration Slug, MI Machine
Shipping Container, MI and CG Adapter
Shipping Container, Electrical GSE
Pressurization and Checkout Kit

The schedule shown in figure 36 indicates the design and development of mechanical ground support equipment necessary to support the Advanced Mariner bus and lander components. The design effort will include the following:

Concept studies and illustrations.
Establish criteria.
Publish program plan, schedules, etc.
Follow vehicle design interface definition.
Mass parameter requirement analysis.
Design calculations.
Layout and layout studies.
Drafting.
Materials coordination.
Schedule maintenance and reviews.
Vendor liaison for special products.

The development efforts include the following:

Fabricate subsystem and system test models and fixtures.
Carry out tests of subsystem and system fixtures.
Report results and incorporate changes, if any.

The mechanical GSE follow-up effort should include the following:

Manufacturing and vendor liaison.
Engineering changes to meet design requirements.
Design change requests and failure reports.

As indicated in the schedule, the MGSE is available for subsystem handling during the assembly of the system test vehicle, which takes

RE-ORDER No. 64-525

place from the third quarter of 1966 through the third quarter of 1967, and it is therefore available for system handling during the system tests. This equipment is subsequently used for handling the flight vehicles after the completion of type approval testing.

2.5.5 Problem Areas

2.5.5.1 Bus

Two of the more critical problem areas for the bus are in the attitude control program and the separation subsystem development program.

In the attitude control subsystem development program there is a requirement for the development of nitrogen tanks, and these are characteristically long lead time items: not only are they basically long lead time, but their design cannot be completed until much of the rest of the design is finished, since the sizing of the tanks is sensitive to many other aspects of the design, such as weights, moments of inertia, and so forth.

The bus/lander separation subsystem development program is, in concept, fairly straight forward. However, it is a highly complicated subsystem, in which the liklihood of delays or trouble is greater than a simple system. In addition to the single factor of complication, it is significant that pyrotechnics are characteristically long lead time items because of the exhaustive acceptance testing required.

2.5.5.2 Lander

Sterilization is the single most critical problem area with regard to the lander. There is nothing in the conceptual design which is not considered sterilizable, but the severity of the requirement makes likely the possibility of problems in this area.

In addition, the problem exists of meeting certain constraints in the handling of the completed vehicle. This aspect of the problem is discussed in more detail in section 2.4, sterilization, and section 2.5, system development.

RE-ORDER No. 64-325

2.6 SYSTEM DEVELOPMENT

2.6.1 Manufacturing

A manufacturing plan closely integrated with the subsystem development programs is required. The manufacturing organization should define producibility methods during the design phase. Mockups should be available not only to aid the designers but to help the manufacturing personnel understand the mounting of components or subsystems, checkout procedures, and assembly procedures. The manufacturing plan should be initiated as soon as the vehicle configuration is defined. Continual revision of the plan is necessary as the design through drawing releases, becomes firm. Integration of the basic fabrication, procurement, and assembly tasks with facilities, tooling, handling equipment, and checkout or inspection requirements, also required regular updating of the manufacturing plan. Requirements such as sterilization must be included in the plan. The manufacturing organization should associate with the design organization during the development and prototype fabrication phases of the program. Much can be learned in handling techniques and component and subsystem fabrication and assembly during the development test programs that will be reflected in the manufacture of systems test and flight vehicles.

Milestone events that affect the manufacturing efforts must be clearly defined. An example is the release of engineering drawings which must be reviewed with respect to allowing sufficient time for processing, tool design and fabrication, procurement and/or fabrication cycles, in-process and final inspection times and sterilization, as required.

Quality assurance test procedures or inspection requirements must be available at the proper time to allow a continuous manufacturing flow.

Problem areas must be anticipated in time to allow either corrective action or an alternate approach to be established. By knowing current status of the task and comparing it to the manufacturing plan and in turn the program plan, problems can be analyzed with respect to schedules and costs.

The manufacturing plan should be broken down into major tasks and subtasks. A breakdown such as the following could be appropriate:

Major Task	1		Fabrication and Assembly of Lander
Subtask	1.1		External Structure
		1.1.1	Forebody
		1.1.2	Afterbody

RE-ORDER No. 64-525

Subtask	1.2	Internal Structure
	1.2.1	Descent Phase
	1.2.2	Landed Phase
	1.2.3	Impact Attenuator System
Subtask	1.3	Main Parachute System
Subtask	1.4	Drogue Parachute System
Subtask	1.5	Payload
	1.5.1	Preentry to Descent Phase
	1.5.2	Landed Phase
Subtask	1.6	Umbilicals
Subtask	1.7	Pyrotechnics
Subtask	1.8	Final Assembly of Lander
Subtask	1.9	Flight Proof or Qualification Test Hardware
Subtask	1.10	Field Spares
Subtask	1.11	Packaging and Shipping
Major Task	2	Fabrication and Assembly of Bus
Major Task	3	Fabrication and Assembly of Vehicle Handling Equipment
Major Task	4	Fabrication and Assembly of Electrical Ground Support Equipment
Major Task	5	Fabrication and Assembly of Special Test Equipment

As design configurations become available, the manufacturing plan would become more complete, and task and subtask effort definition would become more detailed. Until the first test vehicle was finally completed and checked out, the manufacturing plan would be a working document under constant revision.

2.6.2 Quality Control Plan

The quality control program plan should be designed to assure a high level of quality during development, fabrication, processing, assembly, inspection, test, maintenance, packaging, and shipping of subsystems and systems. All hardware fabricated within the contractor's plant or at any other source, should be controlled by documented inspection and test instructions at all points necessary to assure conformance to design requirements. Quality control will effectively control purchased materials, work subcontracted, and in-house fabrication and assembly by establishing inspection and documentation requirements for all purchase orders and manufacturing orders.

To implement this control, the quality control effort covers three basic areas of operation: planning, inspection, and measurements.

a. Quality Control Planning

Planning personnel will be responsible for reviewing the requirements of the contract to make provisions for the special controls, processes, test equipment, fixtures, tooling, and skills required for the program. They also will be responsible for the correlation of inspection and test results with manufacturing methods and processes and for providing appropriate review and action to assure compatibility of manufacturing, inspection, testing, and documentation. They will also be responsible for recognizing the need for an initiating corrective action, when necessary, to update testing techniques, instrumentation, documentation, and quality instructions and procedures. Quality control planners will prepare and issue inspection, test and documentation procedures and instructions for specific nonreoccurring tasks that arise during the implementation of the quality program and are not covered specifically by the existing procedures and instructions, for example, retesting after a rework or replacement operation.

b. Inspection and Acceptance Testing

The inspection personnel will be responsible for performing the inspection and test operations as specified in the various work instructions, such as test procedures and planning procedures and the preparation of required records, logs, and data sheets. Inspection and acceptance testing is basically performed in three areas: receiving inspection, in-process inspection, and acceptance tests.

c. Measurements

All data relative to purchased material quality level, in-house manufactured quality level, unsatisfactory vendors, vendor surveillance

RE-ORDER No. 64-525

actions, corrective action reports, scrap and rework activities, and Material Review Board activity should be collected, tabulated, and statistically analyzed.

2.6.3 Systems Testing

2.6.3.1 Temperature Control Unit Systems Test

General system tests are to be carried out on a system composed of real but not necessarily qualified hardware. Where possible all equipment must be operative by remote control and performance characteristics measured through GSE. From a thermal point of view, substitution of actual internal hardware with dummy heating loads is acceptable. All equipment on the craft should be checked-out at subsystem levels before installation in the space chamber for the temperature control test. Instrumentation lines and vital cabling are carried through the chamber wall to read-out and GSE is placed outside. Before pump-down subsystems check-out is again made and when successful the vacuum pumps are started. After steady pressure (10^{-5} torr or less) has been established, a simulated flight sequence will be initiated: cruise mode-burning maneuver-cruise mode.

In order to evaluate the complete system, the testing is not confined to specified mission time requirements, however for most severe heat conditions, extended operating time durations (50 percent) should be applied. Similarly, for most severe cold conditions, minimum equipment operating times are used in order to ascertain that equipment can be switched on at very low temperature levels.

The general system testing shall ascertain that no performance degradation takes place in the temperature region 0-120°F and that no malfunction or catastrophic failure occurs when equipment is switched on between -15°F to 140°F. In addition, the thermal design must bear out that the above limits are not exceeded during all operating phases of the mission.

2.6.3.2 Systems Integration and Life Tests

The first sets of qualified subsystems hardware will be allocated to the systems integration vehicle. Although there will be the usual amount of interface control and system coordination up to this time, this second spacecraft development vehicle will be the first time that representative hardware will be truly integrated. To gain every advantage possible from this integration and test vehicle, an early detailed test planning effort is programmed with adequate lead time to allow the test engineers and technicians to be thoroughly trained on each of the principle subsystems by participating in the vendor qualification programs, as well as the assembly and test of the temperature control vehicle.

The first step in accomplishing the systems integration test program shown on figure 37 will be the bench mated electrical tests of the various subsystems as they become available. Test cable attachments and dummy loads will be used wherever required to gain early knowledge of subsystems electrical incompatibility, which can be fed back into subsystem test and production. The beginning of mechanical integration of the spacecraft systems will follow shortly after the initiation of the bench test program to also identify what mechanical changes are necessary as soon as possible. This bench and integration test will be conducted in conjunction with the assembly of the vehicle to serve as a training of factory assembly and test technicians as well.

At such time as all of the subsystems check out reasonably well and can be subsequently assembled, detailed system testing will be started. It is during this phase of the program that a complete "ringing out" of all subsystems can be accomplished. Environmental conditioning will be utilized whenever possible to verify the results of the temperature control vehicle program. Subsystem operational and design changes resulting from tests with this vehicle will be made and verified prior to incorporation into other units. In the overall plan the scheduling of this test program is such to allow for maximum use of this vehicle to test adequately all design changes that may have originated from any sources.

One of the final series of tests to be performed is the RFI test according to accepted NASA standards. Due to the many rf subsystems on board both the bus and lander, plus the complete dependence on the DSIF commands for successful mission accomplishment, these RFI tests will be of utmost importance.

Although the test report to be issued is shown late in the test sequence, a practice of daily status reports will be established so that all interfacing disciplines are cognizant of all problems as early as possible and can take immediate actions as required.

Following the completion of the systems integration testing, a system life test will be performed. The schedule for this activity is shown in figure 38.

It is expected that it will take about two months to refurbish and ship the vehicle to the life test site. The refurbishment will allow for the addition of any small changes or the repair of any minor damage done during the integration tests.

Once at the test site, the vehicle will be set up in the high vacuum chamber, assembled in flight configuration, and checked out to be sure that all the subsystems and components are working properly.

The test is conducted so as to represent as accurately as possible a real mission with all time spans being the correct ones. Some variation from a completely correct mission will have to be allowed, however, because of problems in handling certain pyrotechnic sequences, for example, such as disposing of the sterilization canister in a one g environment. Solutions to these problems are not critical, however, as long as the element of maintaining mission life is not disturbed, and as long as certain events such as engine starts can be carried out after prescribed lengths of time. To the greatest extent possible, this test should represent an actual flight, and if possible, the chamber vacuum should be maintained for a full 280-day mission simulation.

The test will be concluded about three months before launch in 1969, allowing for the possibility of minor changes in the nonsterilized portion of the spacecraft prior to flight.

It is expected that it will take about one month to remove the vehicle and equipment from the chamber.

2.6.3.3 Structures System Tests

During the early stages of development testing certain element and full scale tests will be conducted on the structure in support of the final design and analysis. Up to this point a complete lander assembly will not be available, since final design release will not have occurred. When the third complete structural system is available certain system tests must be conducted to verify the final design analysis and to support other dynamic analyses by establishing influence coefficients. These system tests shall be conducted in three phases: 1) static tests based around the critical design environments, 2) vibrational tests to establish frequency responses and natural modes, and 3) additional static tests to failure.

The first phase, static tests, is essential in the design of a lander to substantiate that all areas of stress concentration have been fully evaluated in the structural analysis and design. In the previous development programs only element and/or full scale subsystem tests were conducted to develop the structural design and hence, the final structural design will not have been tested as a system. This test shall perform this function and hence support the structural analysis. All critical environments imposed on the design of the lander shall be simulated in the test condition as static loads programmed to actual time functions. Only limit (operational) loads shall be applied initially. Full instrumentation of this test will be required, including strain and deflection measurements. The displacement data will then be used to obtain the influence coefficients necessary in the final analytical dynamics analysis of the lander.

While this data is being reduced and reviewed in terms of the final design, the second phase, vibration tests, of the structural system test program will be performed. The first requirement here is that the lander be capable of withstanding the critical vibration environments during the flight history. These usually exist during spacecraft launch from Earth. Full range random and sinusoidal input loadings will be applied and lander responses recorded. Any damages noted will be rectified on the test specimen and in the design release. This test will also substantiate the analytical model used in the dynamics analysis.

The second requirement is that the natural frequencies and transmissibilities of the lander must be known in order that guidance systems can be properly designed for both the launch vehicle and spacecraft. This basically requires two types of testing, 1) free-free model response test independent of interfaces (launch vehicle or flyby/bus) and 2) the complete spacecraft (lander and flyby/bus) response test where the natural frequencies and transmissibilities will be evaluated to ensure that dynamic coupling does not exist between pertinent systems which could hinder guidance and control systems on both the launch vehicle and flyby/bus.

After the vibration test program completion this same unit will be returned for the third phase, complete ultimate static tests to final failure. The primary purpose of the ultimate test program is to substantiate the final structural analysis margins of safety. In order to accomplish this, ultimate loads (factor of safety times limit loads), under the same design environments established for the phase one limit static test, will be applied to the structural system. All instrumentation used previously will be again employed with emphasis on the strain data, which is necessary to determine the margins of safety. Finally, the static loads will increase beyond the ultimate condition to the onset of failure, the specimen repaired, and tests repeated over again under different conditions until all critical conditions have been explored. Thus complete knowledge of the modes of failure and margins of safety can be obtained. Even though this test is basically a verification test, results can feed into the final design prior to the first flight unit fabrication.

In conjunction with the lander system testing, the bus will be subjected to the spectrum of vibration loads corresponding to the inputs during the various operational modes, i.e., from the boost, cruise mode attitude control, and main propulsion thrusting and thrust vector control. A check will be made to determine whether equipment and flyby/bus structure are constrained within the dynamic envelope.

Static structural load tests will be conducted combining the maximum axial and transverse loads and increasing these loads by the amplification factor to get the total maximum loads in each operational mode. Specifically, the spacecraft-booster adapter section and the flyby/bus-lander adapter section will have to be structurally tested in the launch mode. For the other modes of operation, the critical interface will be the solar panel hinges.

2.6.3.4 Type Approval Testing

A completely assembled lander and bus should be subjected to a Type Approval Test. Tnis testing should be performed for two configurations; the capsule and bus mated to form one assembly and the capsule and bus as individual units. The major objectives of the testing of these configurations is as follows:

1) Lander type approval test

a) Demonstrate that the performance of the lander remains within specification requirements before, during, and after environmental exposure as required.

b) Demonstrate that the hardware can withstand the heat sterilization cycle with a sufficient factor of safety.

c) Demonstrate that the lander as packaged for shipment can withstand the shock and vibration conditions associated with handling and transportation and in the unpackaged configuration can withstand any unfavorable climatic conditions associated with storage.

d) Demonstrate that the heat balance of the lander is such that while being exposed to a vacuum and the level of solar energy existent between Mars and Earth the temperature of the capsule will be within specified limits.

e) Demonstrate the functional capability of the sterilization cannister removal system and parachute system.

f) Prove that the crushup mechanism will function as required.

2) Bus type approval test

a) Demonstrate that the performance of the bus remains within specified requirements before, during, and after environmental exposure as required.

b) Demonstrate that the bus as packaged for shipment can withstand the shock and vibration conditions associated with handling and temperature and if the unpackaged configuration can withstand unfavorable climatic conditions associated with storage.

c) Demonstrate that the heat balance of the bus is such that while being exposed to a vacuum and the solar radiation intensity existent between Mars and Earth, the temperature of the bus will remain within limits.

3) Lander and bus assembly type approval test

a) Demonstrate that the lander-bus assembly will function in accordance with specification requirements before, during, and after exposure to expected environments.

b) Demonstrate that the lander-bus assembly can withstand the shock and vibration associated with the boost phase of the mission cycle.

c) Demonstrate that the heat balance of the lander-bus assembly is such that under exposure to vacuum and solar radiation varying from that level existent near the earth to the level existent near Mars is such that the operating temperature of the lander-bus assembly will remain within limits.

d) Demonstrate the functional capability of the bus-lander separation system.

4) Environments considered

The environmental conditions that should be used for the Type Approval tests are listed in table 7. Sand and Dust, Salt Fog, and Fungus testing are not included due to the fact that the expected logistics preclude the possibility of exposure to these environments. As a safety measure, an explosive atmosphere test is included to help safeguard against accidents on the launching pad. Also required is an R. F. Interference test.

RE-ORDER No. 64-525

TABLE 7

Transportation Handling, and Storage

a. Handling Shock

b. Bench Handling

c. Drop Test

d. Humidity

Manufacturing

a. Explosive Atmosphere

b. RF Interference

Powered Flight

a. Vibration

b. Staging and Ignition Shock

c. Static Acceleration

Flight

a. Vacuum Temperature

b. Mars Entry Deceleration (Lander only)

5) Test methods

a) Preflight environments

The preflight environments of transportation shock and vibration and humidity are nonoperating tests which should be performed in accordance with applicable Mil Standard specifications. As such this testing does not warrant any special discussion.

The Type Approval sterilization dry heat cycle test requirement is for three 36 hour temperature soak cycles at 145° C.

b) Safety environments

(1) Explosive atmosphere

For the explosive atmosphere test, the capsule and bus assembly will be installed in a chamber containing an explosive mixture of fuel and air. While being exposed to this atmosphere, the capsule-bus assembly will be operated in the same manner as will be done during prelaunch checkout. This test will guard against the possibility of a catastrophy on the launch pad.

(2) RF interference

Tests will be performed to determine if the electrical equipment aboard the capsule-bus assembly can emit or be susceptible to signals which could be dangerous to range safety. Further, evaluation of rf interference characteristics with respect to cross talk between channels which results in degradation of quality of transmitted data will be tested. This test will be performed on the bus-lander assembly and the two units separately. Testing may be done without roler paddles and with simulated internal power.

c) Powered flight environments

(1) Vibration

This testing should consist of random vibration tests and a simusoidal sweep vibration test. For this testing, a group of thrusters (small shakers) can be used. The shakers should be programmed to operate in phase or 180 degrees out of phase for a push-pull operation as required by the configuration of the particular test. For this testing, the vibrations should be applied through the booster attaching ring. This test would be a nonoperating test. Upon completion of the test, the operation of the lander-bus assembly should be verified for conformance to specification requirements.

(2) Shock

Shock testing should be performed to simulate shocks produced by staging and ignition shocks that occur during the boost phase of flight. To perform the testing, the capsule-bus assembly will be affixed to a free fall drop test machine. The shock will be applied through the booster assembly mounting ring.

The test will be a nonoperating test. Upon completion of the required shock testing the operation of the lander-bus assembly should be verified for conformance to the specification.

d) Extra-terrestrial flight

(1) Vacuum-temperature

A test vacuum condition simulating the space environment should be performed on the lander-bus assembly and the lander and bus separately. This testing will need to be done in a space chamber that is capable of maintaining a vacuum of at least 10^{-5} torr. The chamber must be equipped with a source of simulated solar radiation which can be varied in intensity from the level that occurs near Earth to that near Mars. The walls of the chamber should simulate the infinite heat sink of outer space.

Throughout the performance of this test all hardware must be operating. The test essentially will serve as a short duration flight simulation test during which the complete flight of the space vehicle from the earth to Mars can be simulated on the ground. The test will be programmed to evaluate the heat balance of the space vehicle throughout the interplanetary flight and demonstrate that all equipments can function as required under the environment of interplanetary space. The duration of the test will be made as short as possible yet be long enough to evaluate the effect of continuous outgassing on the performance of the satellite.

For economic reasons based upon the presently available test equipments, this testing can be limited to a vacuum of 10^{-5} torr and use of solar simulator that is deficient in energy in the range below wave lengths of 1900A. This will preclude evaluation of cold welding effects and the degradation of surface finishes due to exposure to solar radiation. Presently, such evaluations are only feasible in small space chambers. However, by 1968 there may be large space chambers available which can maintain vacuum conditions of 10^{-9} torr and solar simulators that include simulation of the solar energy below wave lengths of 1900 A.

(2) Mars entry deceleration

The capsule should be subjected to a centrifuge test to simulate the level of deceleration that it will experience on entry into the Mars atmosphere. This test can be performed in conjunction with the boost phase acceleration test using the same centrifuge.

During this test the equipment must be operating. The operation of the equipment should be evaluated for compliance to the specifications during and after exposure to the deceleration environments.

2.6.3.5 Sterilization Unit Assay

The primary concept of sterilization verification for this program is the monitoring, during assembly of lander components and subsystems, of sample hardware, and biologically seeded specimens. On a continual basis these samples will be cultured both before and after sterilization by dry heat to determine biological burden and to check for sterility, respectively. Inasmuch as this will be done many times and in connection with all the subsystems of the lander, assurance is gained that the entire lander will be sterile if every part in it is exposed to the required environment. This technique is the best possible approach to a statistically acceptable method for determining sterilization.

In addition to this method, however, it is planned to examine one entire lander that has been assembled and sterilized exactly in the manner of flight hardware. While this adds little to the statistical guarantee of sterilization, it affords the opportunity to examine in a sterile environment, a lander which is thought to be sterile. It is planned that this lander will be disassembled down to the smallest components, and cultured to determine the presence of live organisms.

The culturing of this vehicle would be carried out in a sterile facility and would be accomplished in basically two ways: small parts such as resistors, transistors, capacitors, and diodes, which could possibly contain organisms internally will either be broken or crushed and cultured in liquid agar. Other parts which, because of their construction or fabrication technique could contain no internal organisms, such as sheet metal, if both sides are exposed, or wire, if the insulation is stripped, will simply be painted with a type of agar which will adhere to the parts in sufficient quantities to promote biological reproduction.

In the event that this exercise yields entirely negative results, then sterility is assured at least to the degree established by the sampling process. In the event, however, that living organisms are found, there will be a specific indication of a sterilization problem. First, it will be known from what part the organisms came from, and second, it may be possible to tell what type of organism it is. Any evidence of organisms found in this manner will most probably be evidence of some handling problem which can immediately be corrected, but which may not have been evident because of the nature of the sampling system.

2.6.4 Problem Areas

2.6.4.1 Bus

The principal systems problem area on the bus is concerned with the mission duration of about 280 days. During this time, some subsystems must remain inactive, then be operated at the end of the flight, while others, such as the attitude control subsystem must operate throughout the mission. This diversity of system operational requirements imposes a severe reliability requirement, and identifies the principal potential problem area for the bus.

2.6.4.2 Lander

The single most outstanding problem area for the lander system is the imposition, as a result of the sterilization requirement, of constraints in handling and test procedures. Once the sterilization cannister is sealed, no further access can be had to the system without destroying sterility, for all practical purposes. Testing procedures, the handling of test data, and in fact even the general philosophy of post sterilization system handling must be different from that expected with a typical spacecraft. Launch site test planning, for example, must be carried out before the design of the cannister is complete, so that the umbilical will contain the correct number of leads. When testing of the sealed unit is carried out, any decision of whether or not to repair anything is not a minor replacement task, but rather a major decision of whether or not to replace the entire spacecraft, or repair and resterilize, which involves opening the cannister, and at least partially disassembling the lander.

This major departure from normal handling methods is likely to cause delays and problems unless planning for this type of handling is carefully carried out.

2.7 FLIGHT HARDWARE

2.7.1 Spacecraft Assembly

Final assembly integrates all the components, subsystems, systems and associated tubing and cabling into a vehicle that will accomplish the mission under the applicable environments.

Prior to assembly of the flight vehicles, experience will have been gained during mockup and test unit fabrication and assembly. Mockup assembly will eliminate interferences between components, brackets, structures, and major subassemblies. Cable and tubing routing will be established. Assembly and checkout procedures can be refined.

Test unit fabrication and assembly tasks will offer the additional opportunity to eliminate problems that affect the final assembly task.

During the test unit fabrication and assembly phase, such support hardware as mechanical ground handling equipment, electrical ground support equipment, and test support equipment will undergo appropriate mechanical and electrical test integration with the test units. This again minimizes problems during the final assembly phase of the flight deliverable vehicles.

It is estimated that the final assembly of both lander and bus and the final integrated testing of the two major assemblies will take four months. The actual assembly of the vehicles is not the governing task during final assembly. The quality control testing at all levels of assembly constitutes the major time allocation during this phase.

Component, subsystem, and system electrical checkout and subsequent debugging will probably cause changes to the time phasing of the assembly plan. The time allocated for this task must include a factor for some rework. The assembly plan must also take anticipated problems of a minor nature into account; and, therefore, must be relatively flexible.

The final assembly of the lander as visualized would proceed as follows:

The lower section of the lander payload sphere is joined with the upper section, both containing units of scientific payload. Antenna and accelerometers are installed next, followed by assembly of the flotation shell and addition of the flotation liquid. The sphère separation shell is added next, followed by attachment of the impact attenuator segments. The resulting landed subassembly is attached to the forebody assembly, and the afterbody assembly is attached in the last major step before checking out and sealing in the sterilization commuter. A detailed discussion of this procedure may be found in Volume III, section 3.3.

The final assembly of the bus will be handled in a more flexible manner. Since the system installation is primarily mounting components and subsystems to a structural framework, accessibility is not as great a problem as with the lander. The sequence installation of the subsystems would therefore probably become overlapping and only a few cases where installation of one part causes an accessibility problem of another part for either installation or checkout, would a particular sequence of assembly be needed.

The last phase of final assembly is the final mating of lander and bus and the subsequent final systems checkouts.

The basic flow plan for final assembly of the Advanced Mariner vehicle is shown in figure 7. It is expected that, of the four months to accomplish the task, more than half the time will be required for quality control functions.

2.7.2 Field Operations

The field operations group will be the "outside" activity to support the systems analysis and control group. As a result, this group will have a support responsibility to accomplish the same over-all program integration and control tasks, plus the prime technical responsibility for the flight operations at the launch site. During the early phases of the development program field operations specialists will coordinate and/or integrate with the appropriate customer agencies, associated booster contractors, and subsystem suppliers to aid in the development of systems and subsystems definition and requirements specifications for program control. In some cases these representatives of this group will be physically located at the various facilities to obtain maximum knowledge for accurate judgement in each assigned area.

As the program progresses through the subsystem test and qualification programs at the vendors, these resident personnel, who have become specialized in each of these subsystems, can return to aid in the accomplishment of a more effective in-house system integration test program. After the completion of these in-house test programs, they would be assigned to the launch site operations staff to direct and/or participate in the conduct of the AMR first vehicle preflight operations plus the normal preflight checkout test program of the subsequent vehicles. Included in these preflight operations would be the usual booster integration program. This series of field assignments will culminate in the responsibility for spacecraft launch operations, the most important phase of the field operations group.

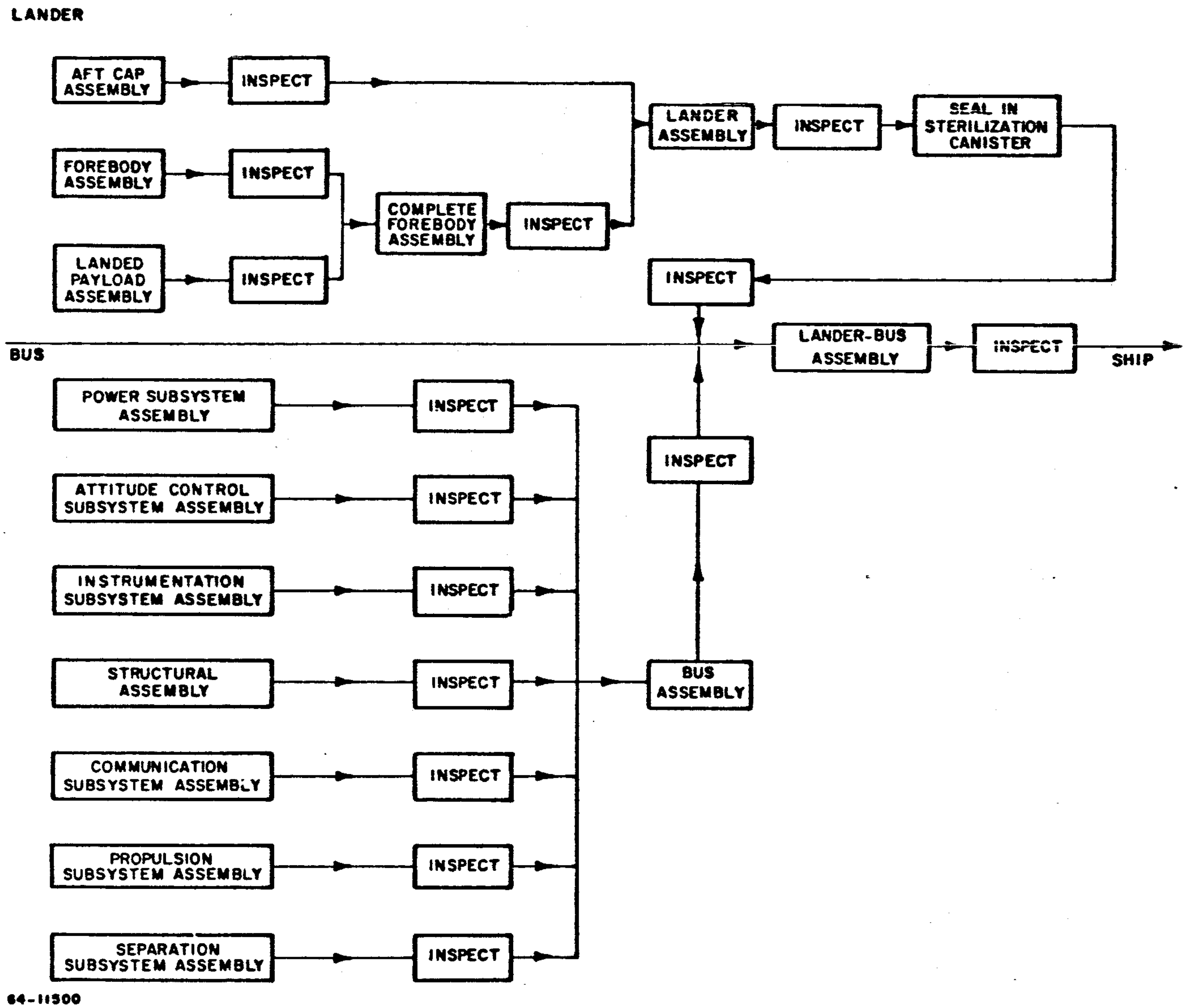


Figure 7 FLIGHT HARDWARE FINAL ASSEMBLY FLOW

The nature of the Mariner mission requires continued wide spread flight operations and command tie-in for several months after launch. These specialized assignments to DSIF stations and command centers will be well suited to these trained total systems-oriented field operation staff technicians and engineers.

2.7.3 Preflight Activities

Figure 39 in the schedules section outlines the type of AMR Preflight Activities program planned for the Advanced Mariner.

When the system integration tests have been completed with the number two spacecraft development unit, it will be refurbished , checked out, and shipped to the launch site to begin a launch site compatibility and integration program. In this way the program will not be subject to a delay due to the final assembly and checkout of any of the flight units. It is expected that two launch pads will be available for each lander opportunity which practically doubles the launch pad readiness programs, emphasizing the importance of an early start.

Representatives of the field operations group who participated in the systems integration test program, will be responsible for the conduct of this compatibility and integration program. Much of the spacecraft systems test knowledge and techniques developed by this group on the systems test can be directly applicable to those similar portions of the launch site tests. In addition, the prior coordination and interface responsibilities with the launch site and booster vehicle contractors will now be applied to hardware integration of the total complex and launch vehicle.

The final ground support equipment compatibility program will also be conducted during this program. Although much of the spacecraft GSE will be similar to equipment already in use at all of the other program facilities, the launch pad requirements, booster vehicle GSE, and launch control equipment operations will not have been integrated with the spacecraft GSE until this time.

The flight vehicles will arrive at the launch site for the final phases of the compatibility and integration program, at which time the actual spacecraft and boosters are mated.

Total system checkouts will be performed with these vehicles with spare spacecrafts available for each launch site in case of unrepairable failure.

The last step of the preflight program will be the countdown sequence to launch.

2.8 SCHEDULES

Assembled in this section of the development plan are schedules of the program activities.

Shown first in figure 8 is a mission schedule showing launch and arrival dates for the two sets of launches being planned.

Shown second in figure 9 is an overall summary of the entire program leading to the 1969 launch. In support of this are shown in figures 10 through 44 detailed schedules of all the significant activities of the program, including details of the 1971 launch which are not shown on the summary.

2.9 FACILITIES

This section indicates some unusual facilities which will be needed for the program preceeded by a discussion of the planning steps which should be carried out by the prime contractor prior to the acquisition of any new facilities.

A five-step method for facilities planning is considered here. It accounts for a variety of problem areas, of which two can be relatively significant: the allocation of facilities either presently being used or already planned and the methods of acquisition of any facilities which may be required in addition.

Following go-ahead, the first step in developing a facilities plan is identifying the job, which in this case includes final design, subsystem development, fabrication, and testing activities. Knowing these types of requirements and the approach being taken with regard to design concepts, critical sizes, and so forth, the facilities required for the job can be determined. This determination is the second step of the facilities planning.

The determination of facilities required involves not only a determination of the type required, but also the required degree of capability. For some types of environmental tests, for example, a vacuum of 10^{-5} torr is adequate, while for others, such as certain materials or lubrication tests, 10^{-9} torr may be required along with additional capabilities, such as solar simulation (which in itself is accomplished in a variety of ways, depending on the specific requirement). It is important therefore at this stage of the plan development to identify only those facilities or degree of facilities which are actually required for completion of the program to the satisfaction of all the technical requirements.

The third step, which should actually be carried on continually as a function of corporate "housekeeping" is the identification of all the facilities available and presently planned within the company. Comparison of availability and requirements should then be made.

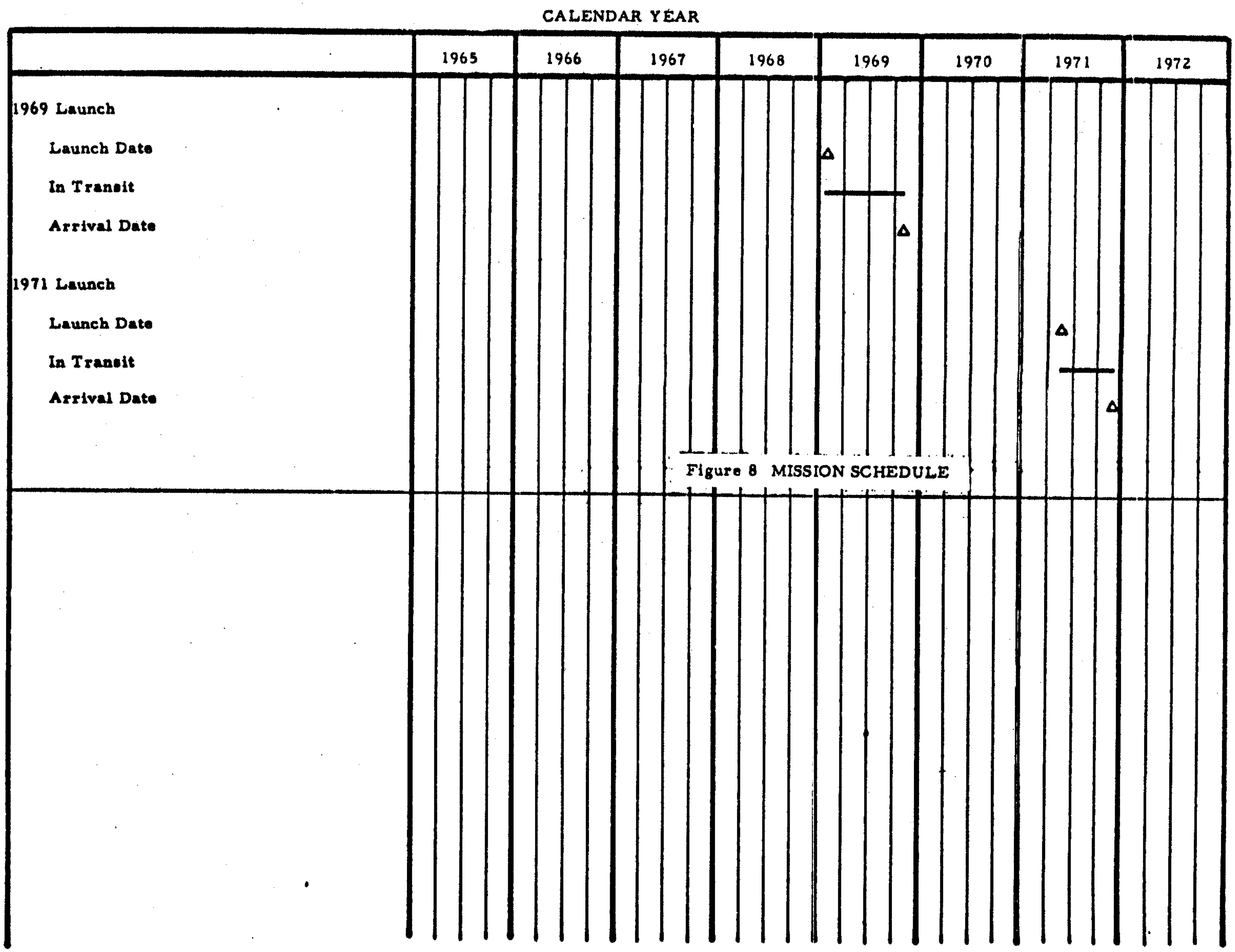


Figure 8 MISSION SCHEDULE

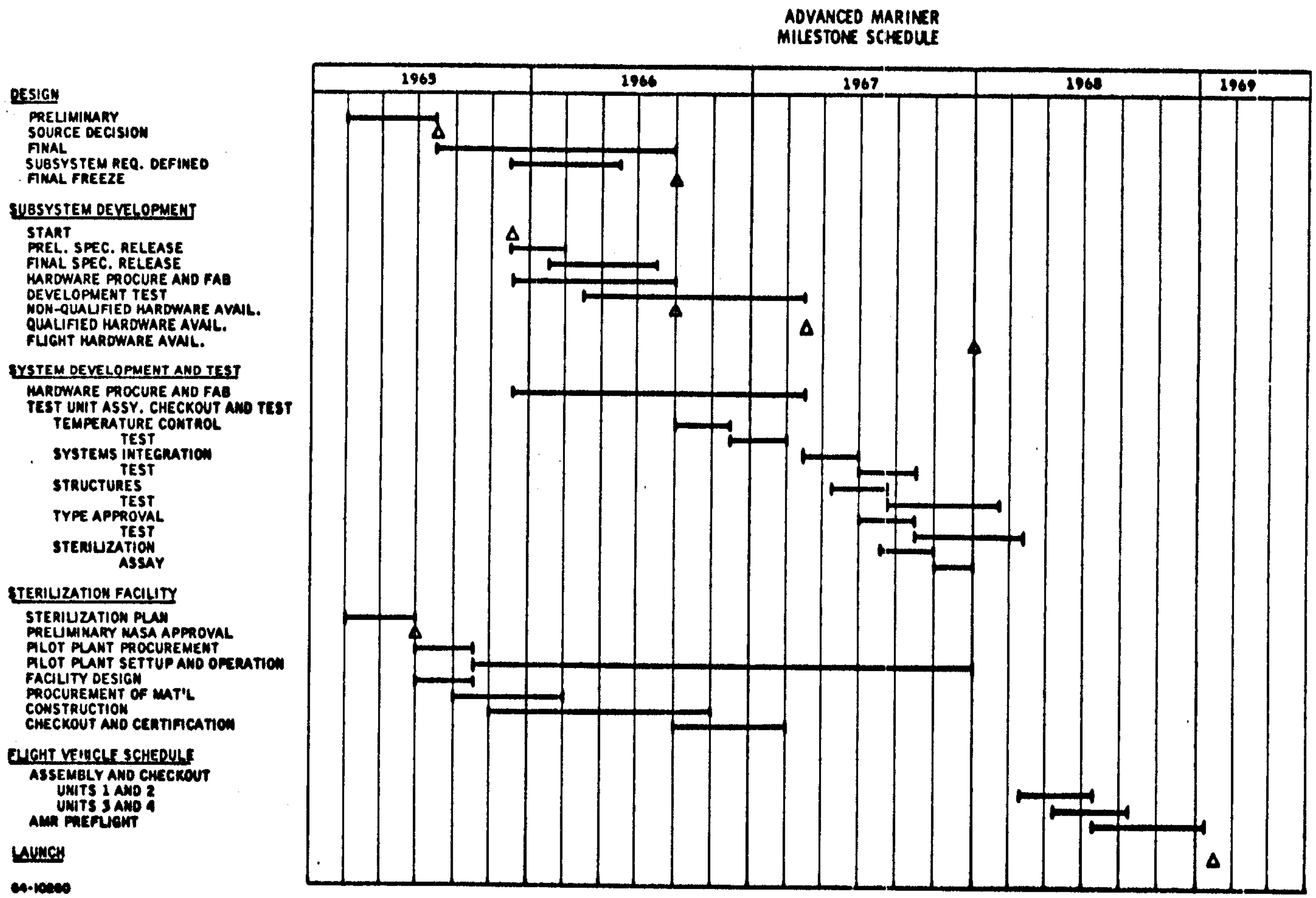


Figure 9 ADVANCED MARINER MILESTONE SCHEDULE

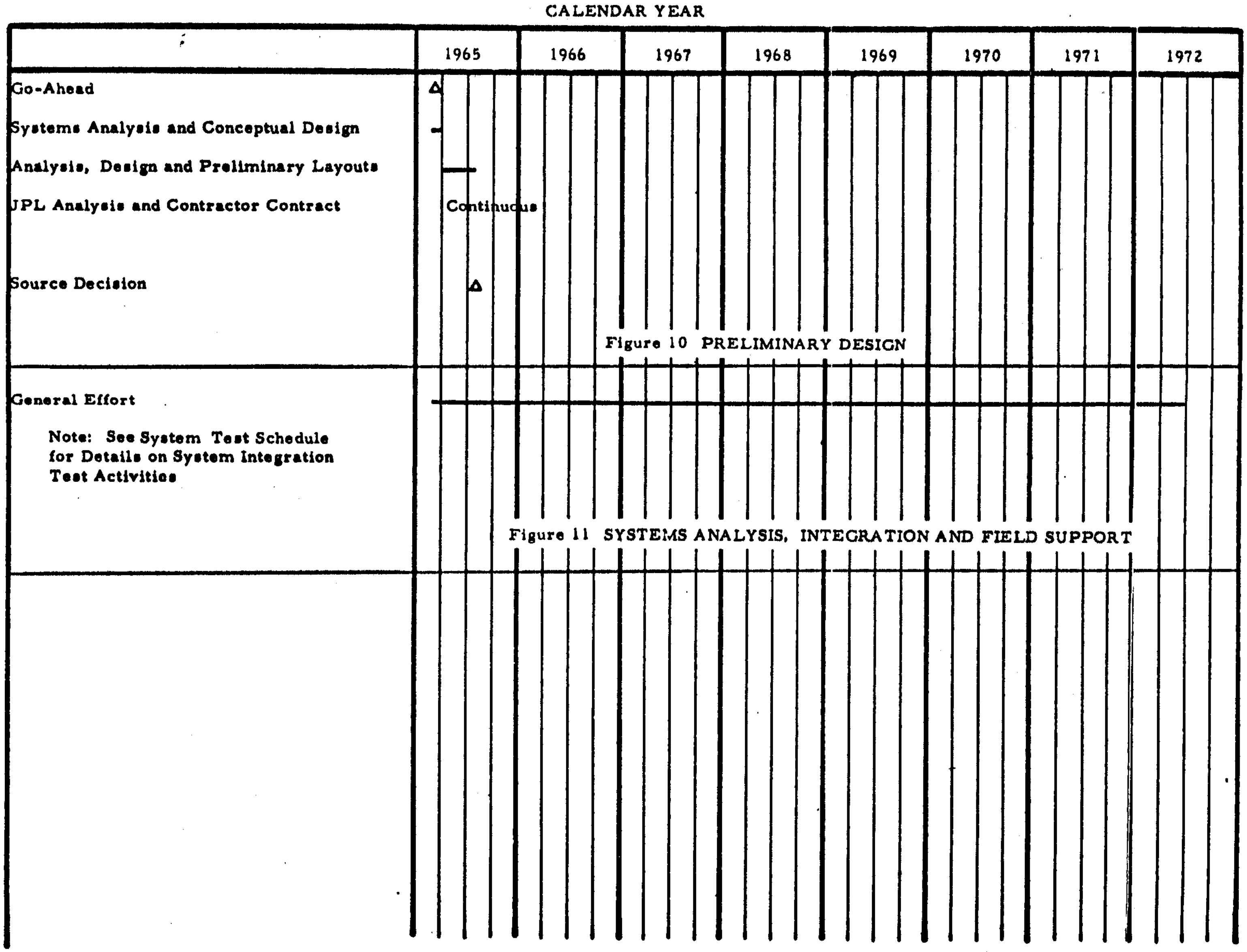


Figure 10 PRELIMINARY DESIGN

Figure 11 SYSTEMS ANALYSIS, INTEGRATION AND FIELD SUPPORT

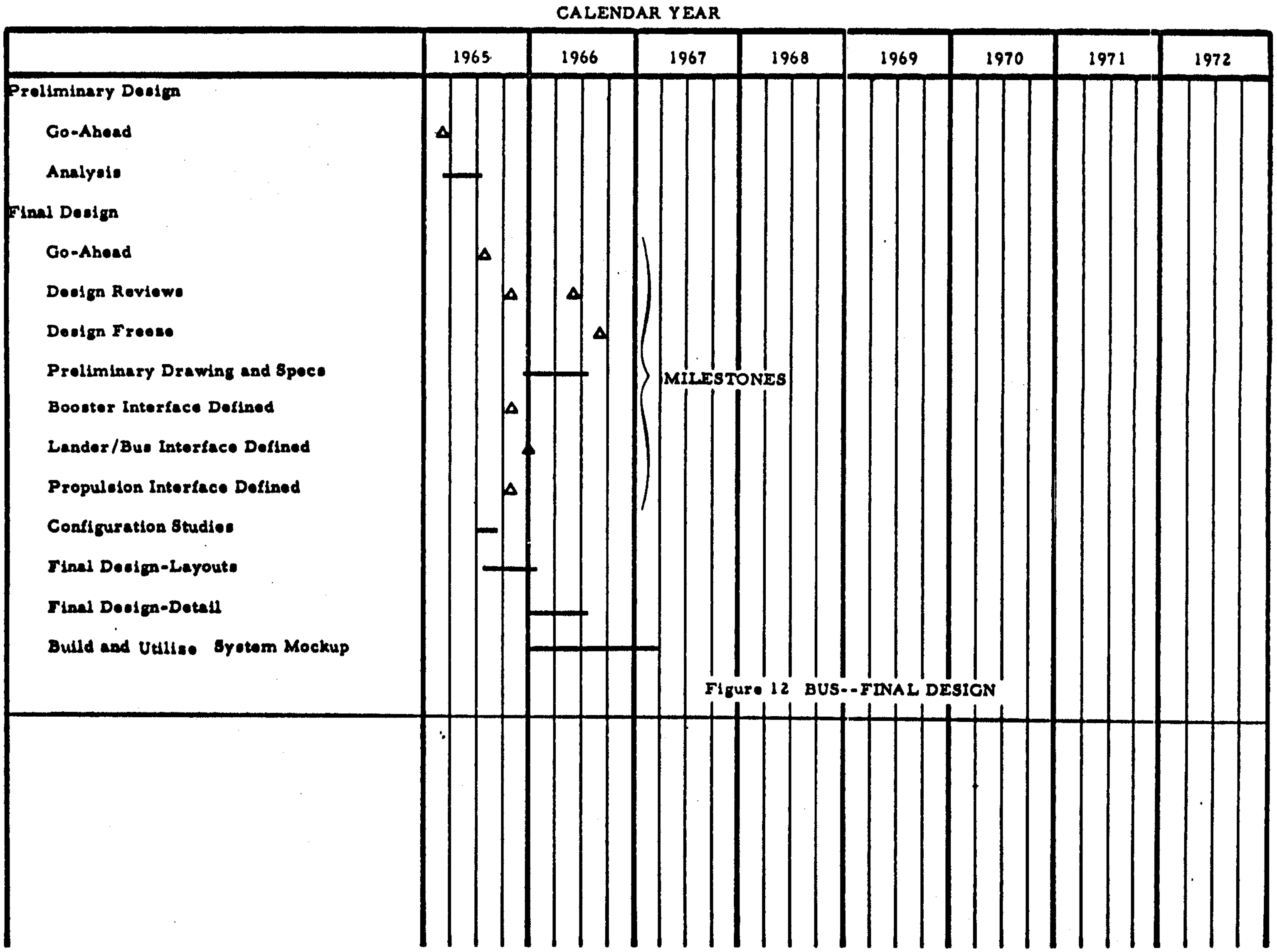


Figure 12 BUS--FINAL DESIGN

RE-ORDER No. 64-525

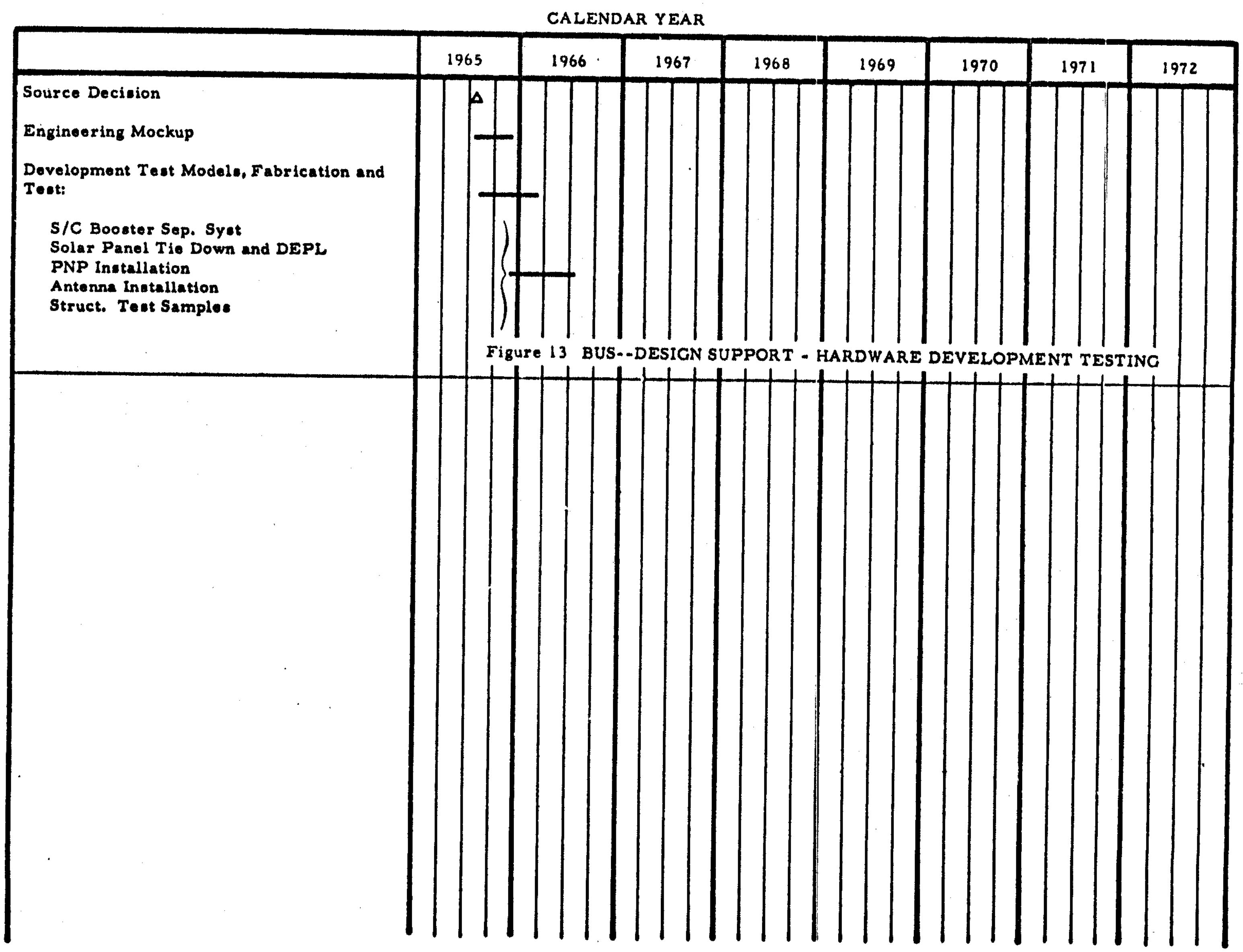


Figure 13 BUS--DESIGN SUPPORT - HARDWARE DEVELOPMENT TESTING

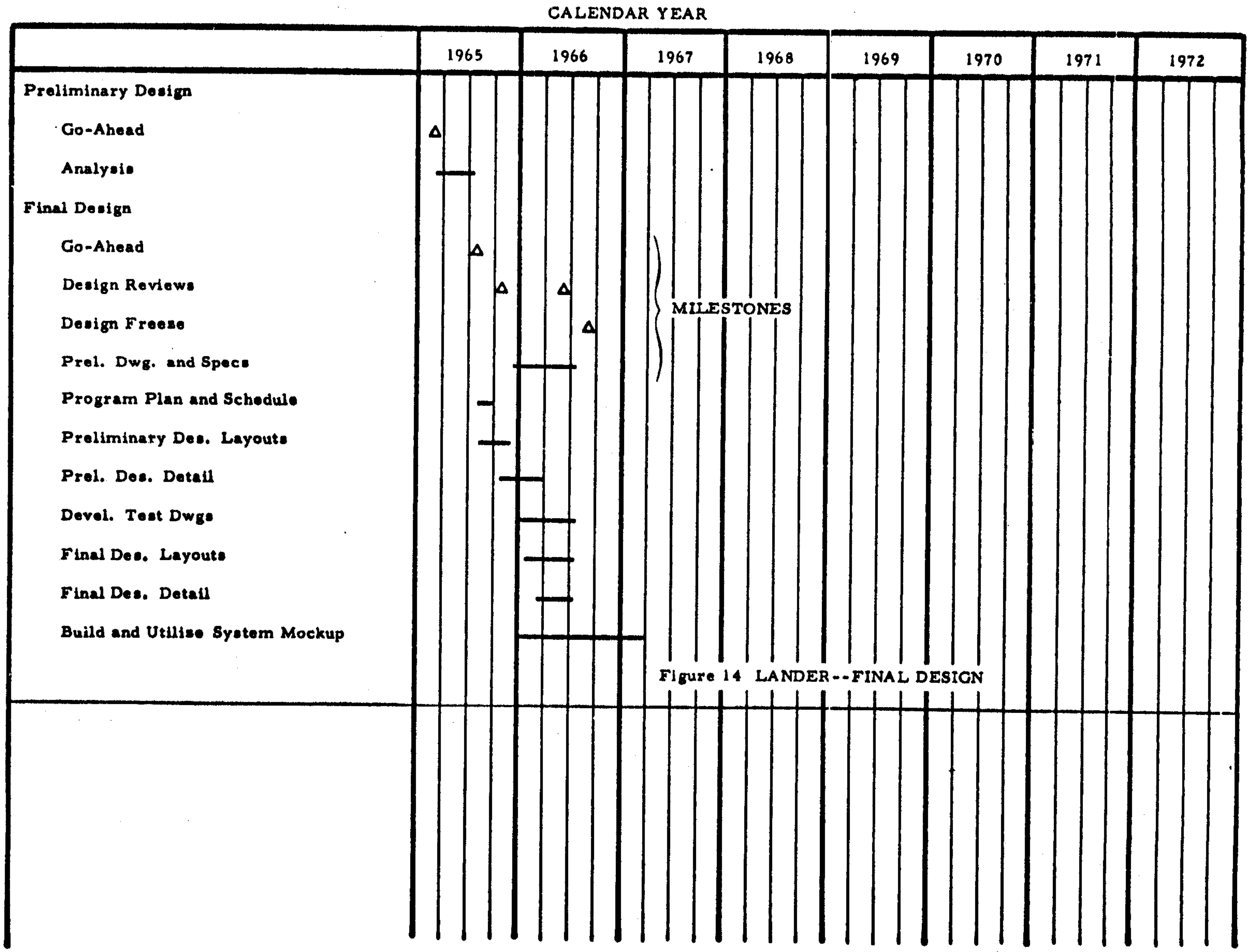


Figure 14 LANDER--FINAL DESIGN

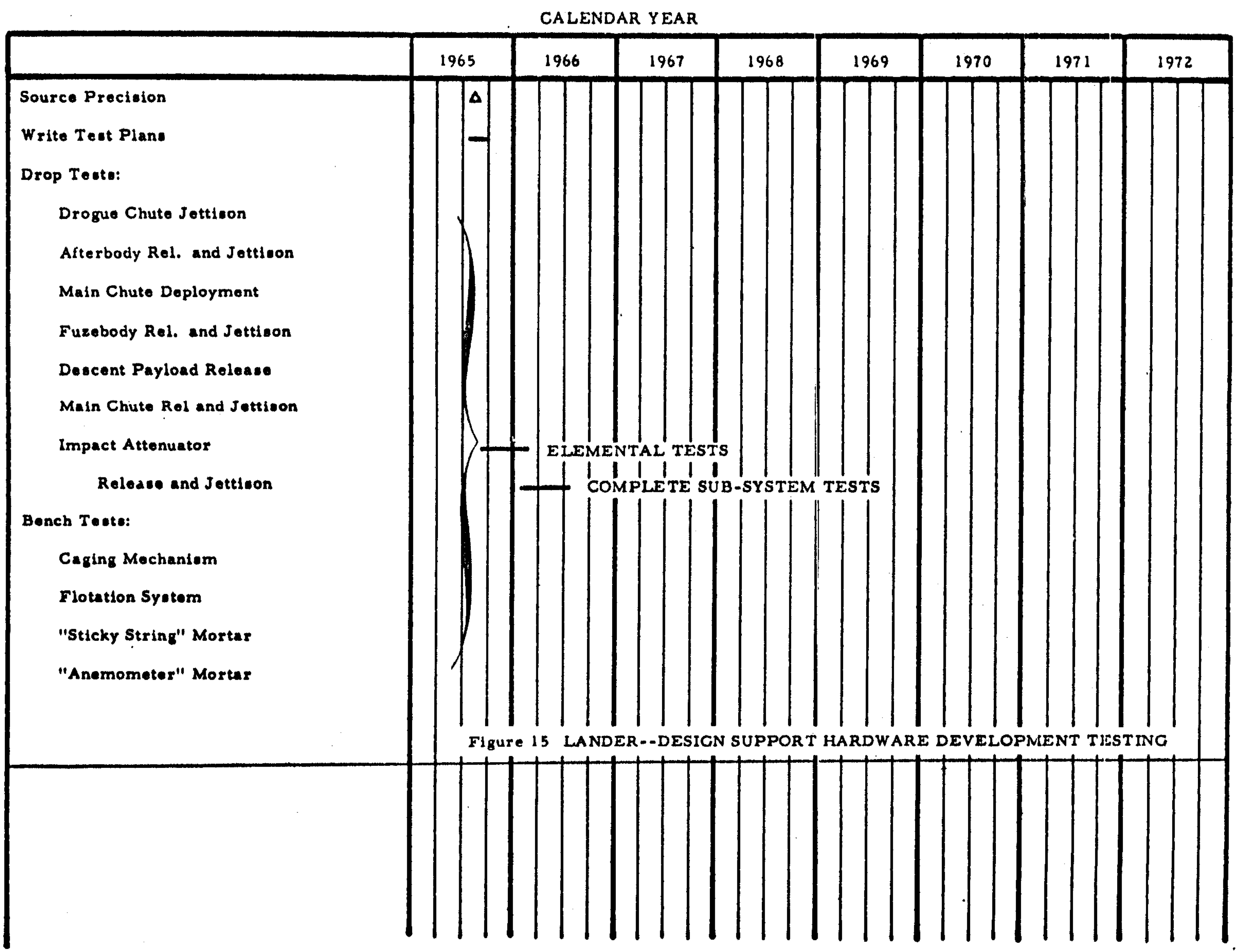


Figure 15 LANDER--DESIGN SUPPORT HARDWARE DEVELOPMENT TESTING

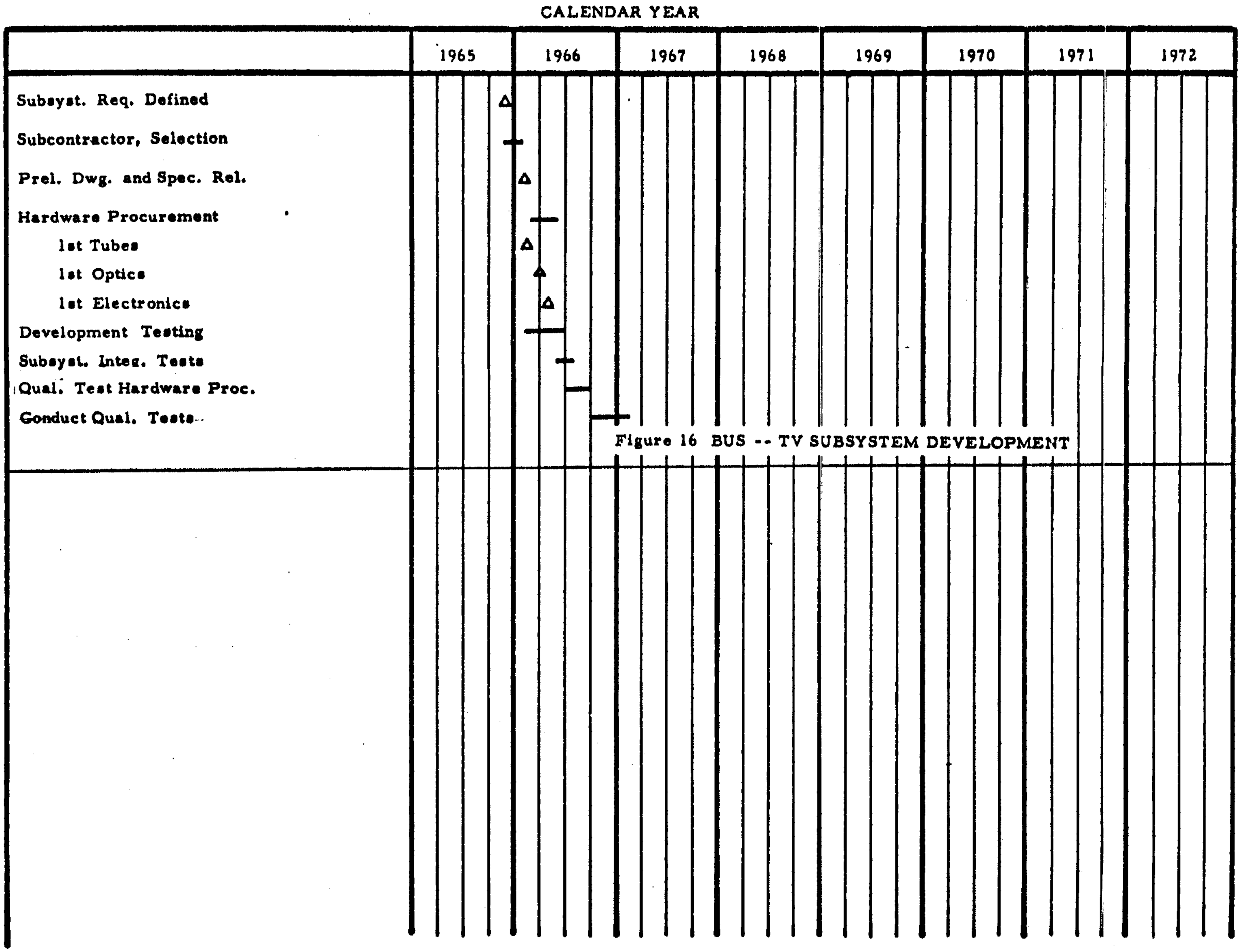


Figure 16 BUS -- TV SUBSYSTEM DEVELOPMENT

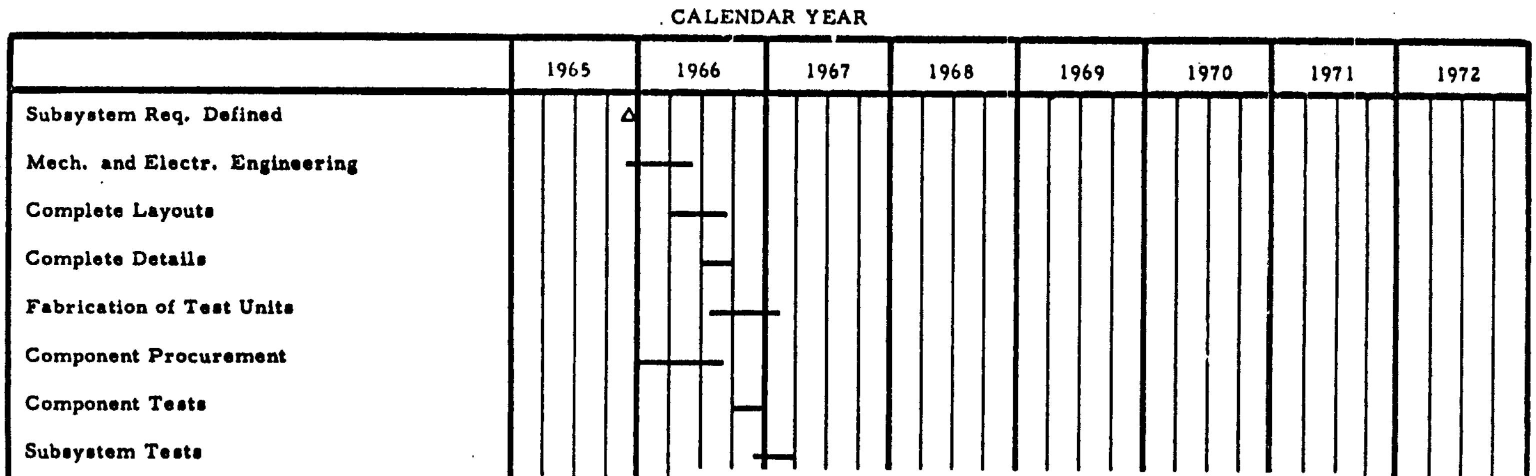


Figure 17 BUS--PAYLOAD PLATFORM DEVELOPMENT

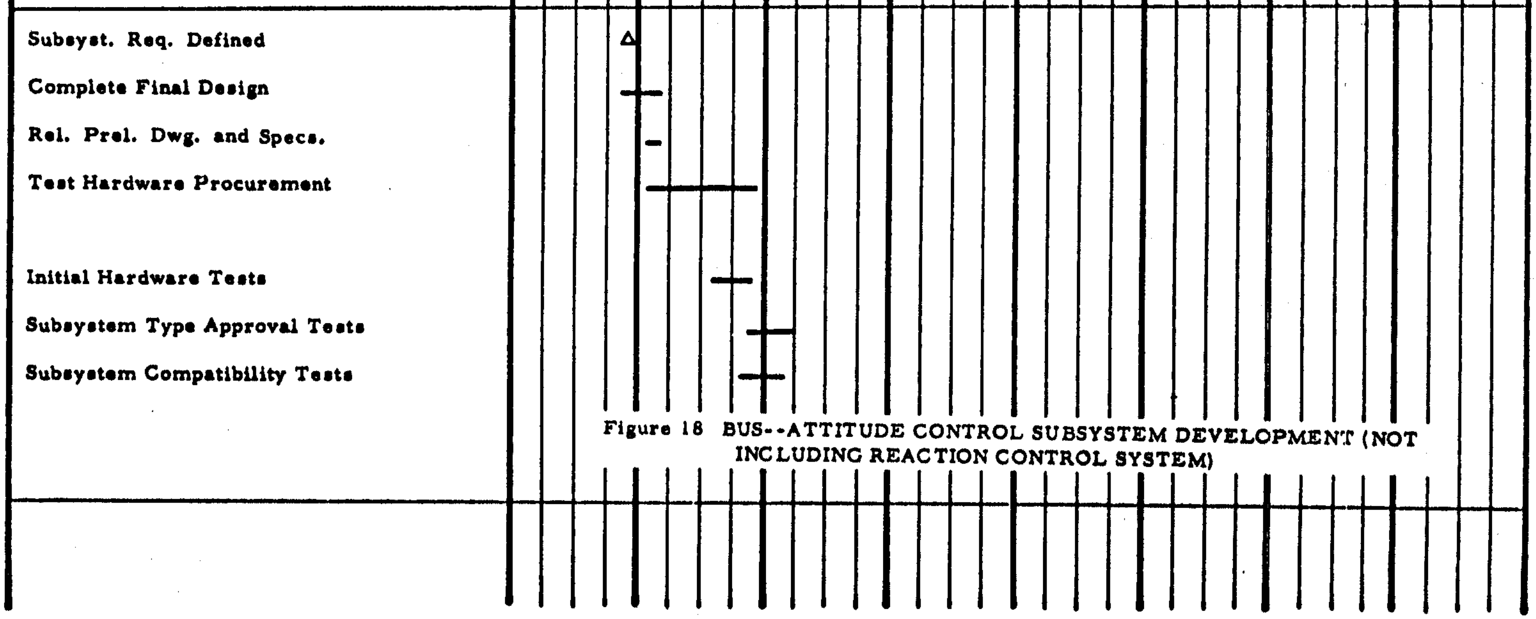


Figure 18 BUS--ATTITUDE CONTROL SUBSYSTEM DEVELOPMENT (NOT INCLUDING REACTION CONTROL SYSTEM)

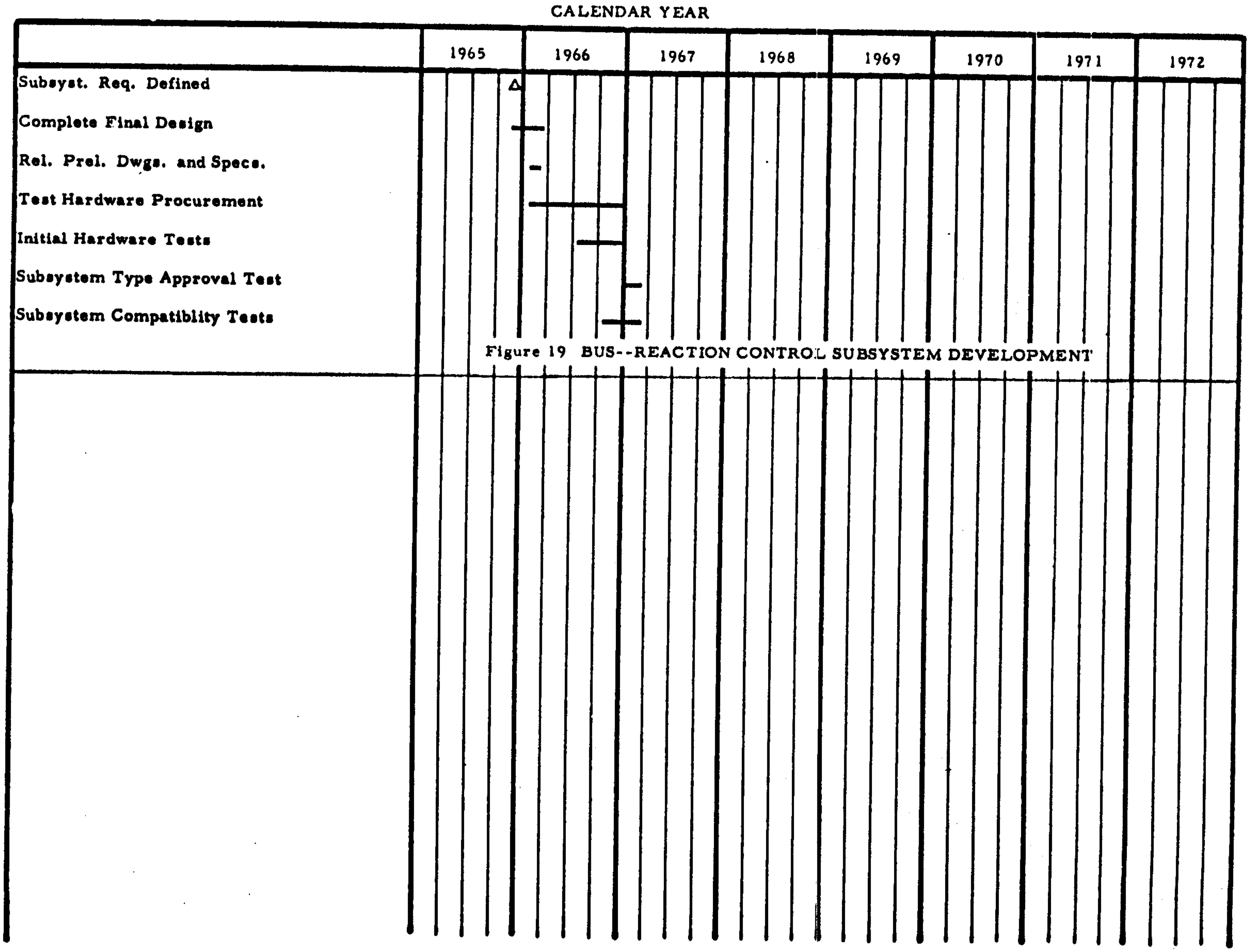


Figure 19 BUS--REACTION CONTROL SUBSYSTEM DEVELOPMENT

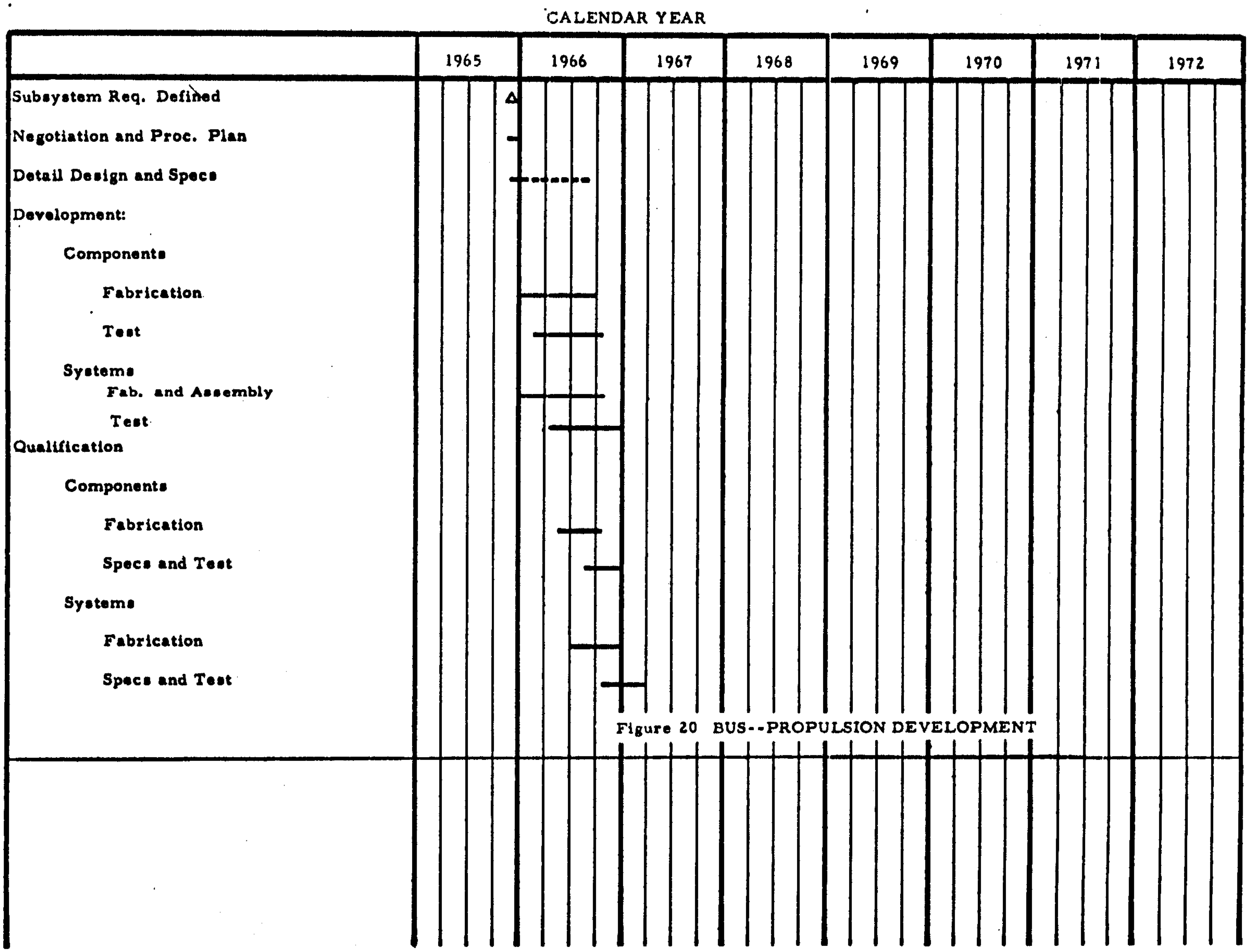


Figure 20 BUS--PROPULSION DEVELOPMENT

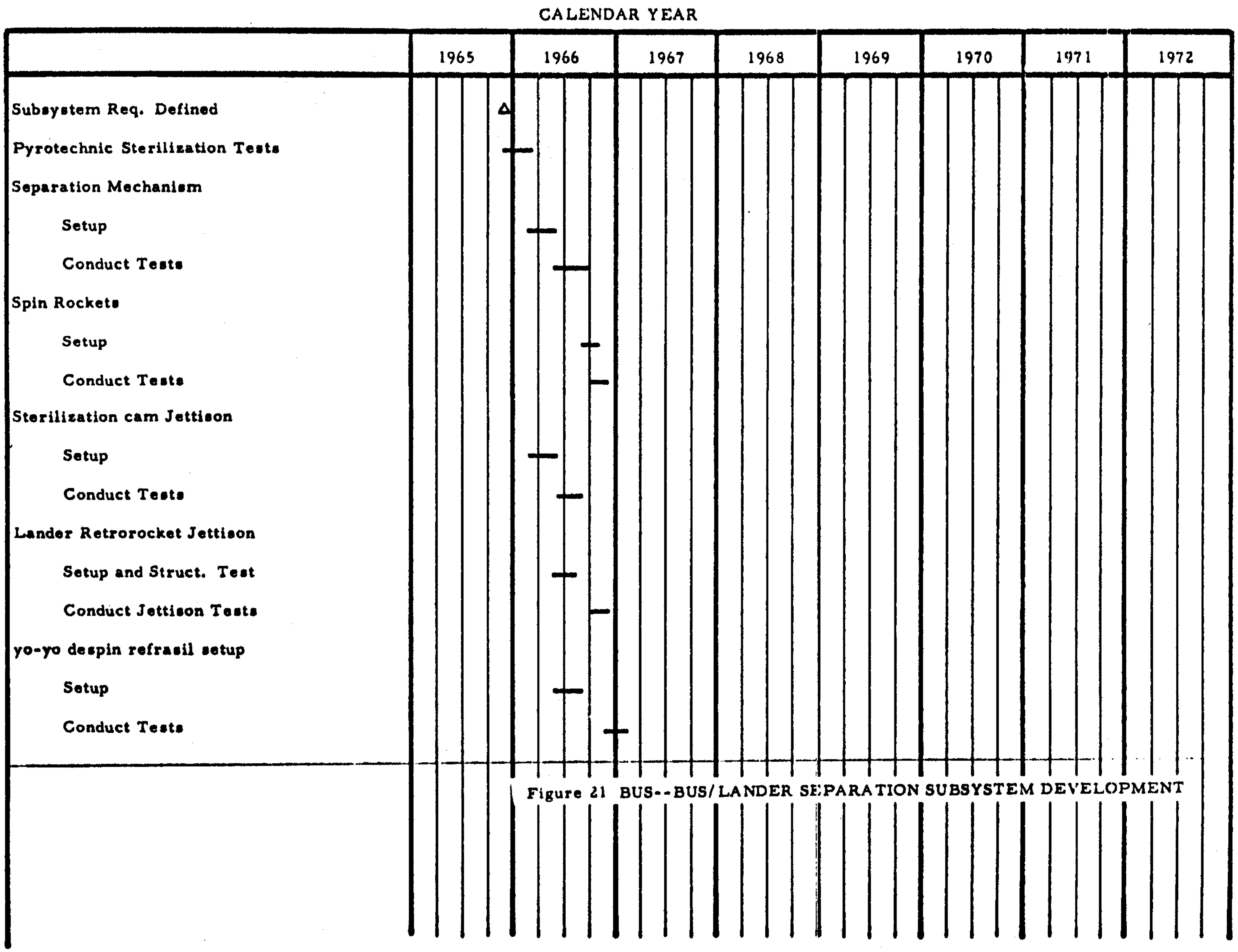


Figure 21 BUS--BUS/LANDER SEPARATION SUBSYSTEM DEVELOPMENT

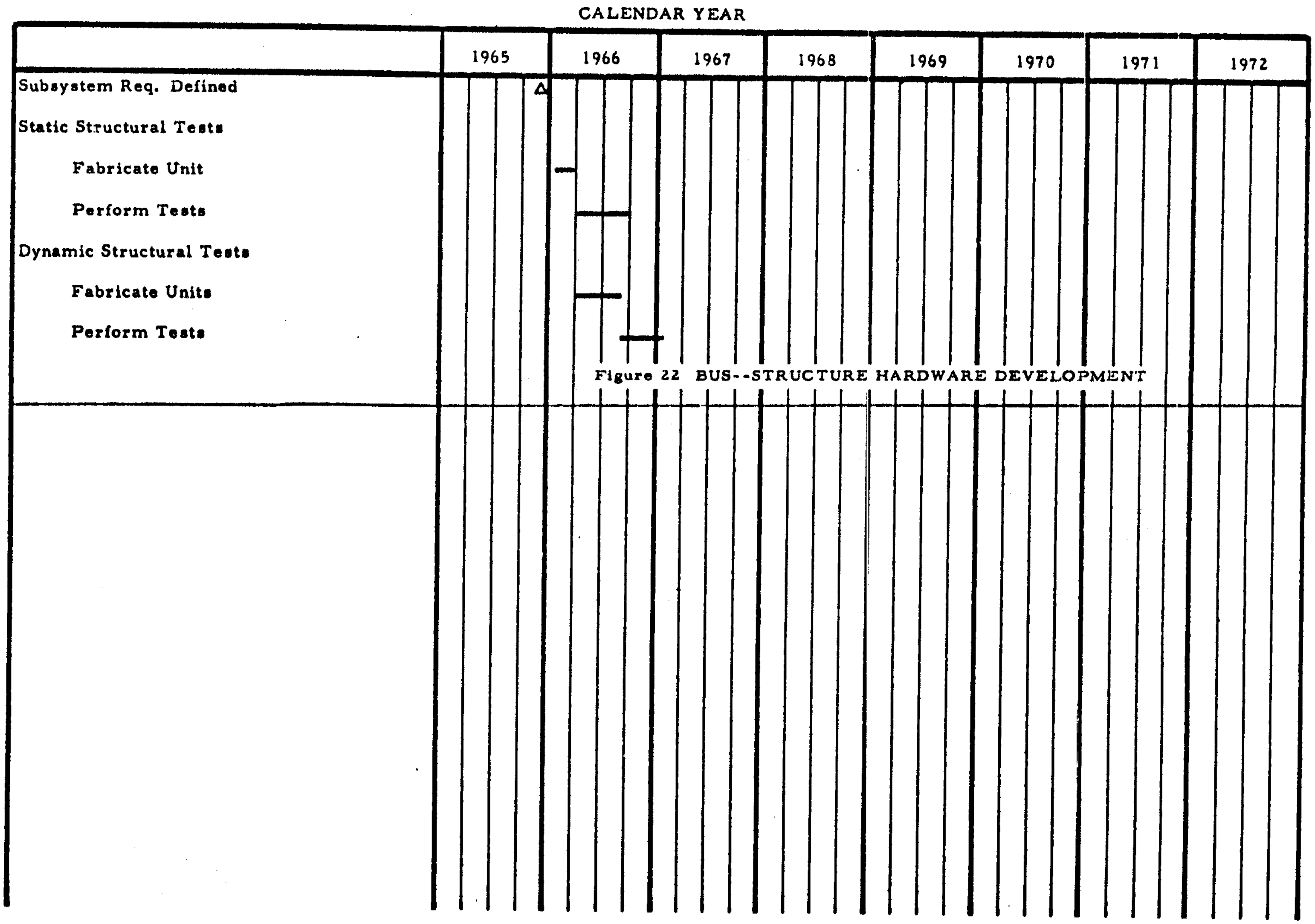


Figure 22 BUS--STRUCTURE HARDWARE DEVELOPMENT

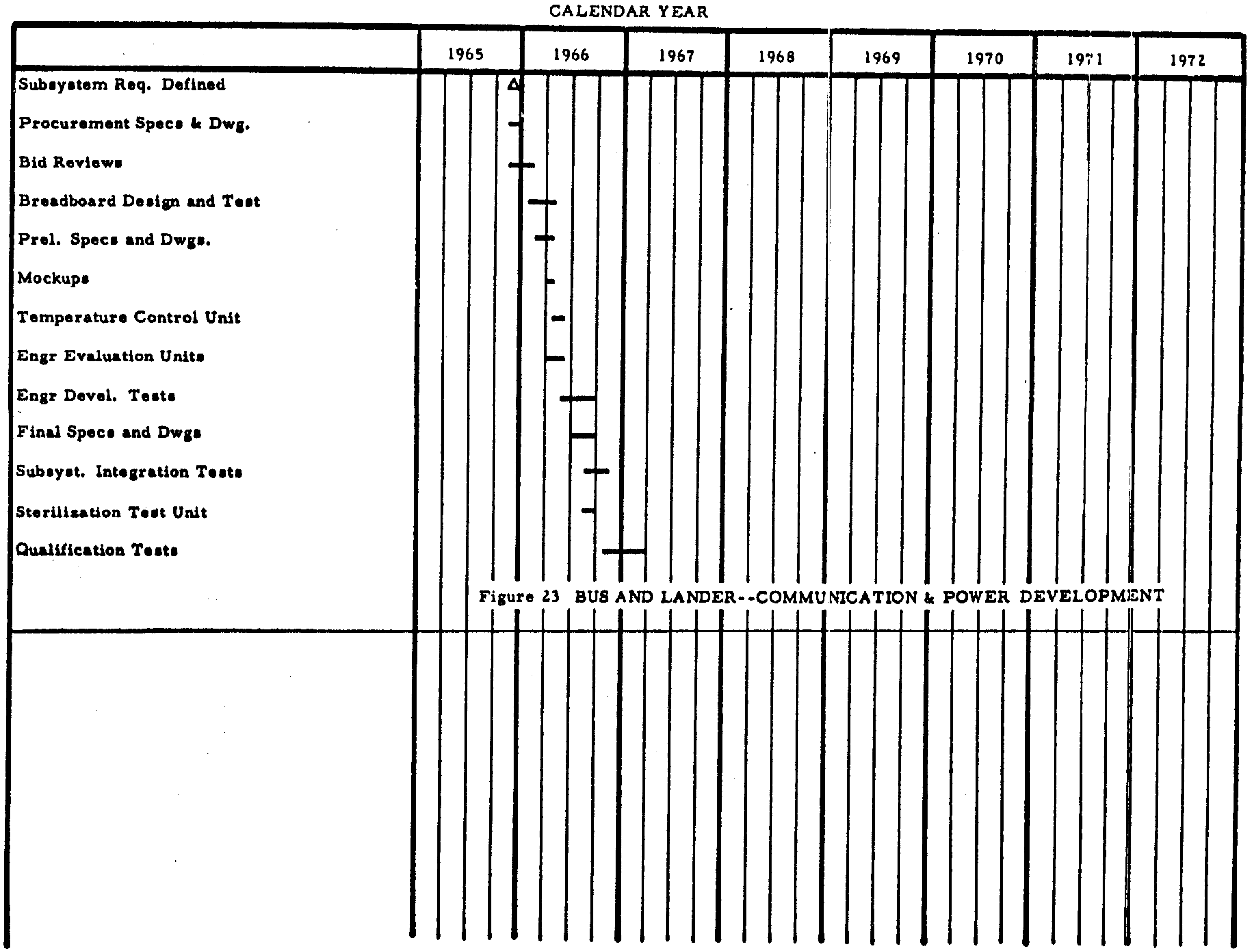


Figure 23 BUS AND LANDER--COMMUNICATION & POWER DEVELOPMENT

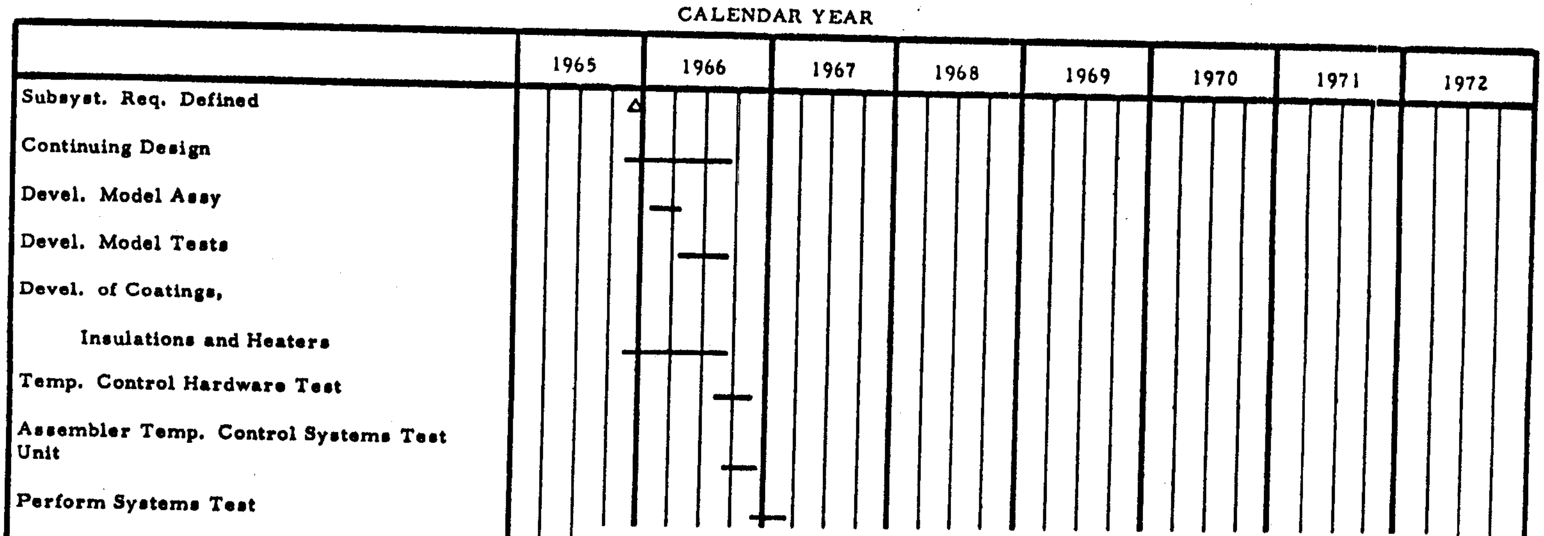


Figure 24 BUS AND LANDER--TEMPERATURE CONTROL DEVELOPMENT

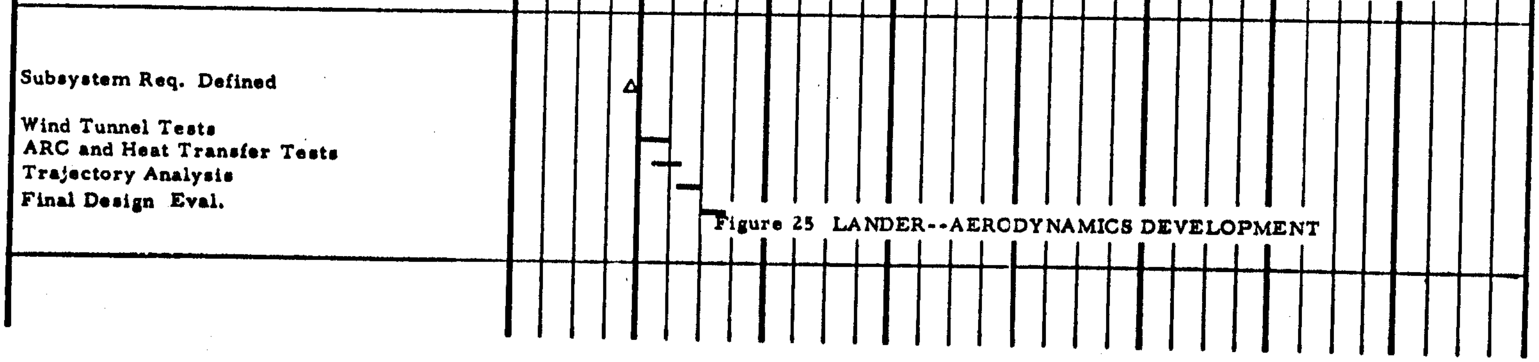


Figure 25 LANDER--AERODYNAMICS DEVELOPMENT

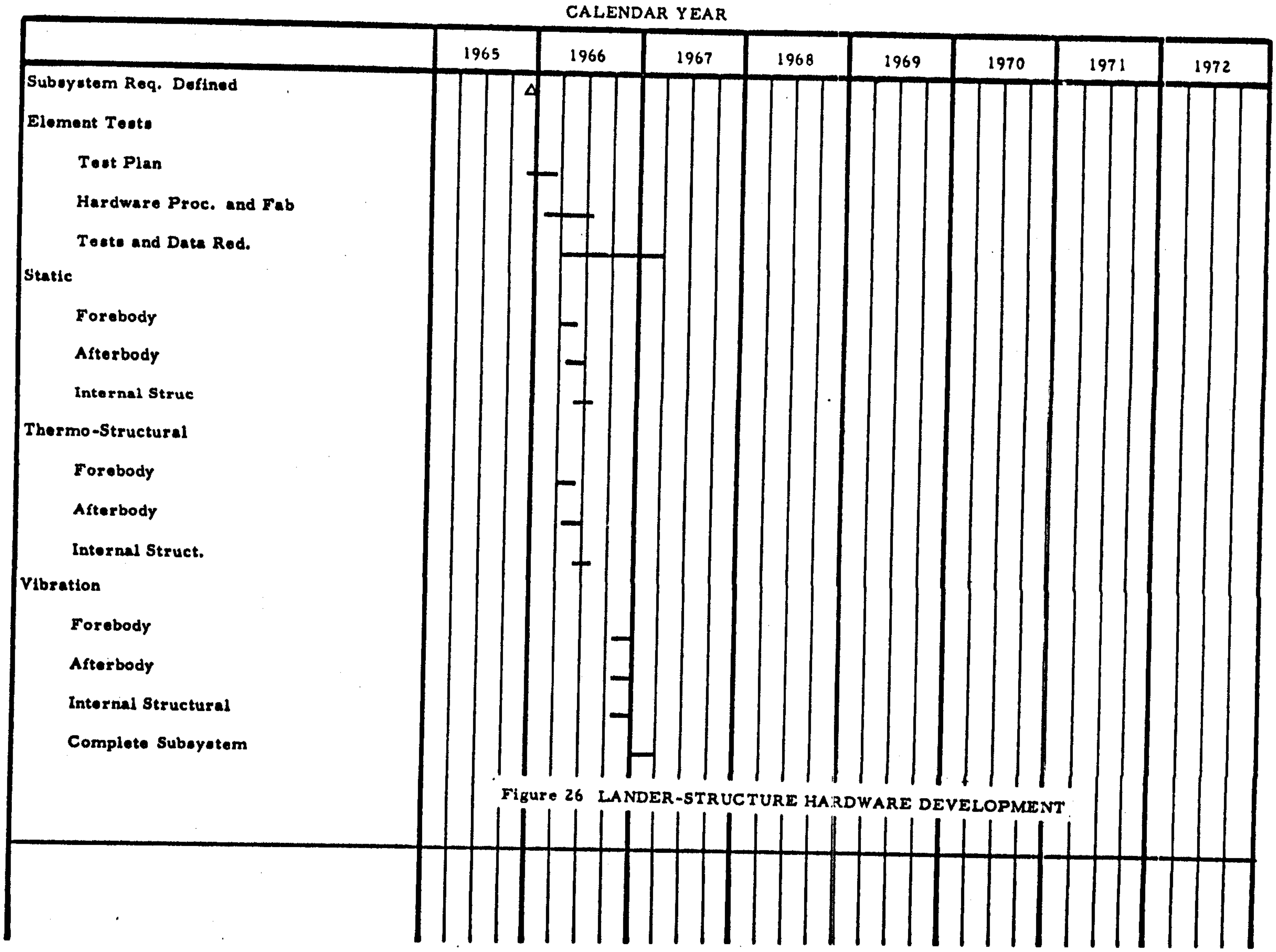


Figure 26 LANDER-STRUCTURE HARDWARE DEVELOPMENT

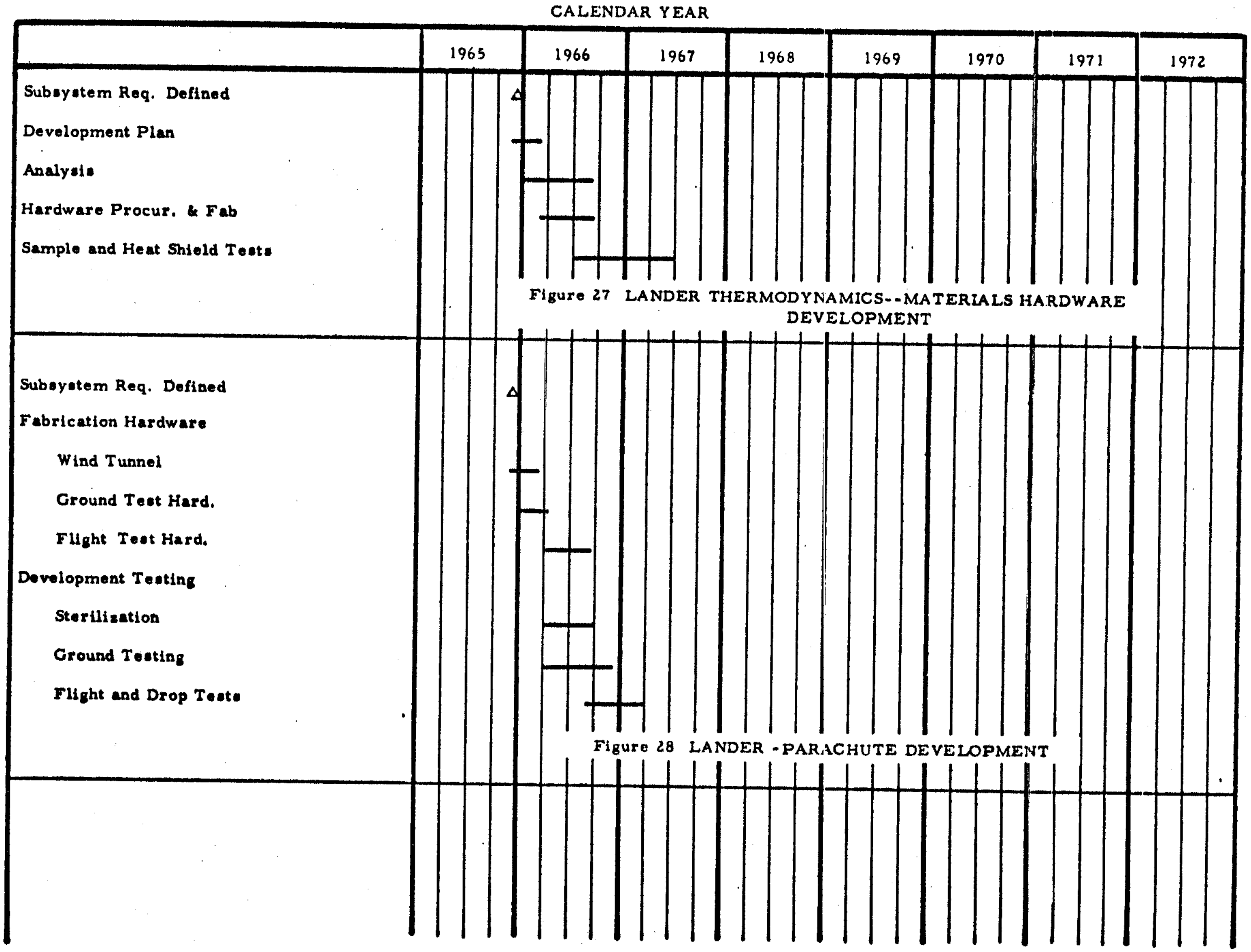


Figure 27 LANDER THERMODYNAMICS--MATERIALS HARDWARE DEVELOPMENT

Figure 28 LANDER -PARACHUTE DEVELOPMENT

RE-ORDER No. 64-525

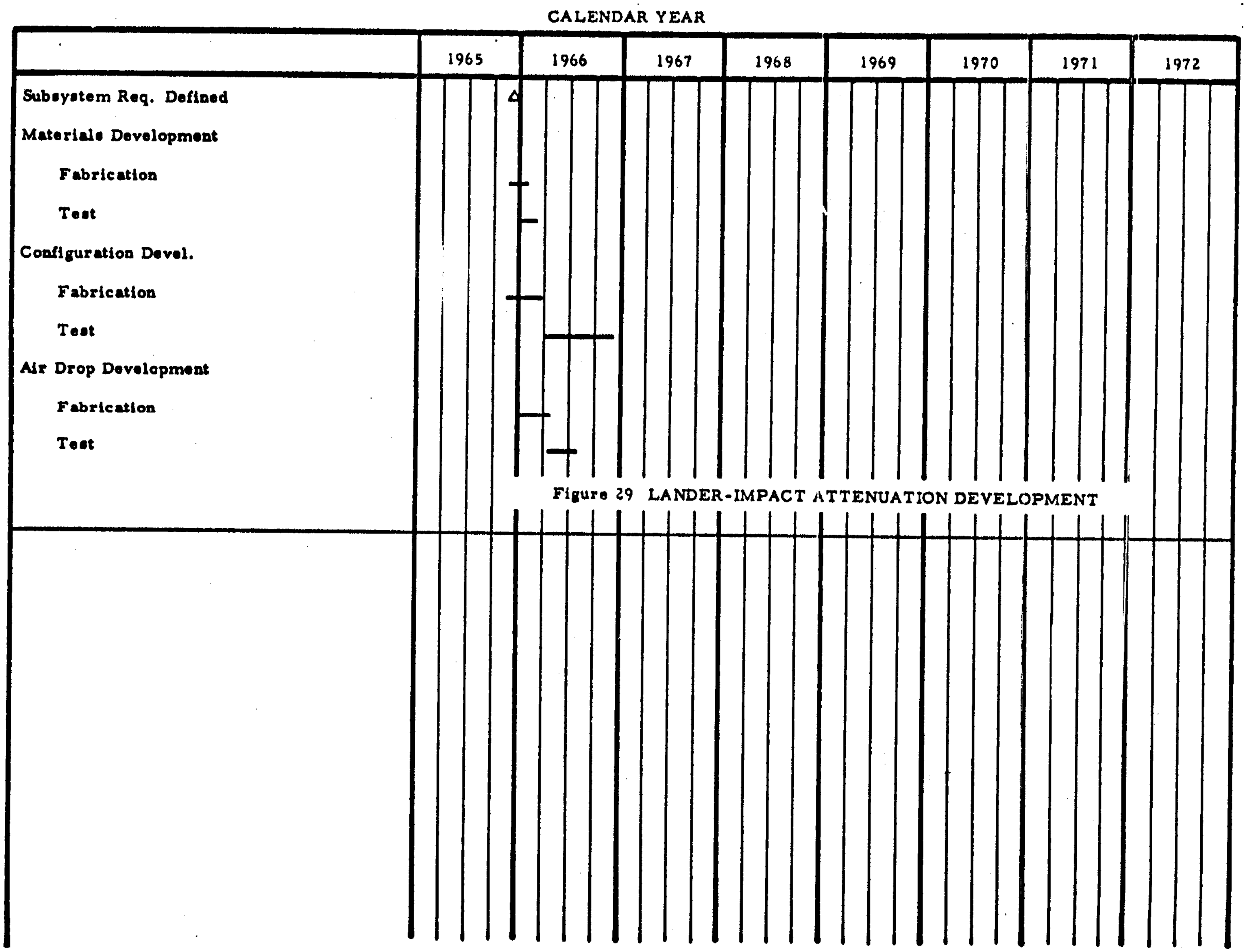


Figure 29 LANDER-IMPACT ATTENUATION DEVELOPMENT

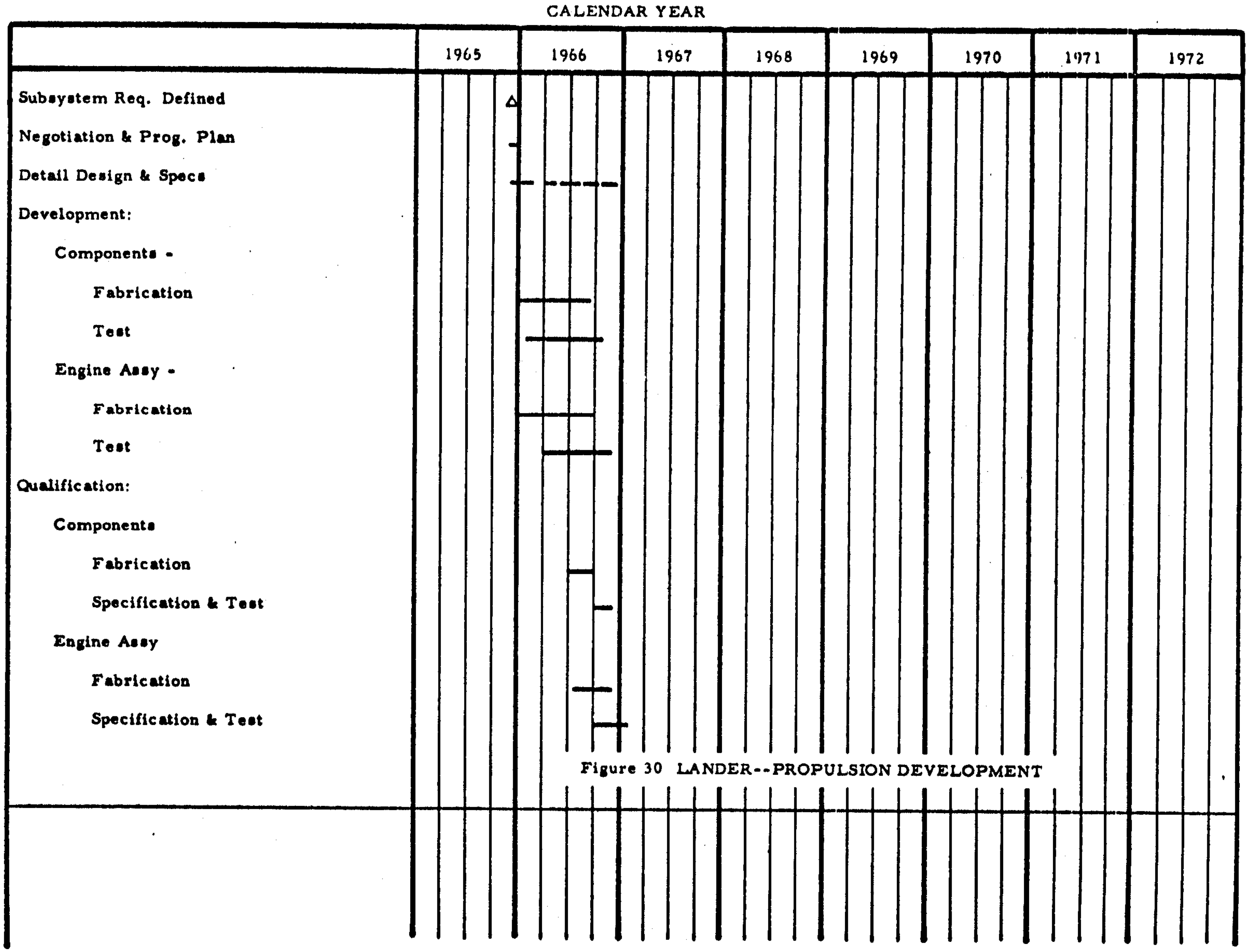


Figure 30 LANDER--PROPULSION DEVELOPMENT

RE-ORDER No. 64-525

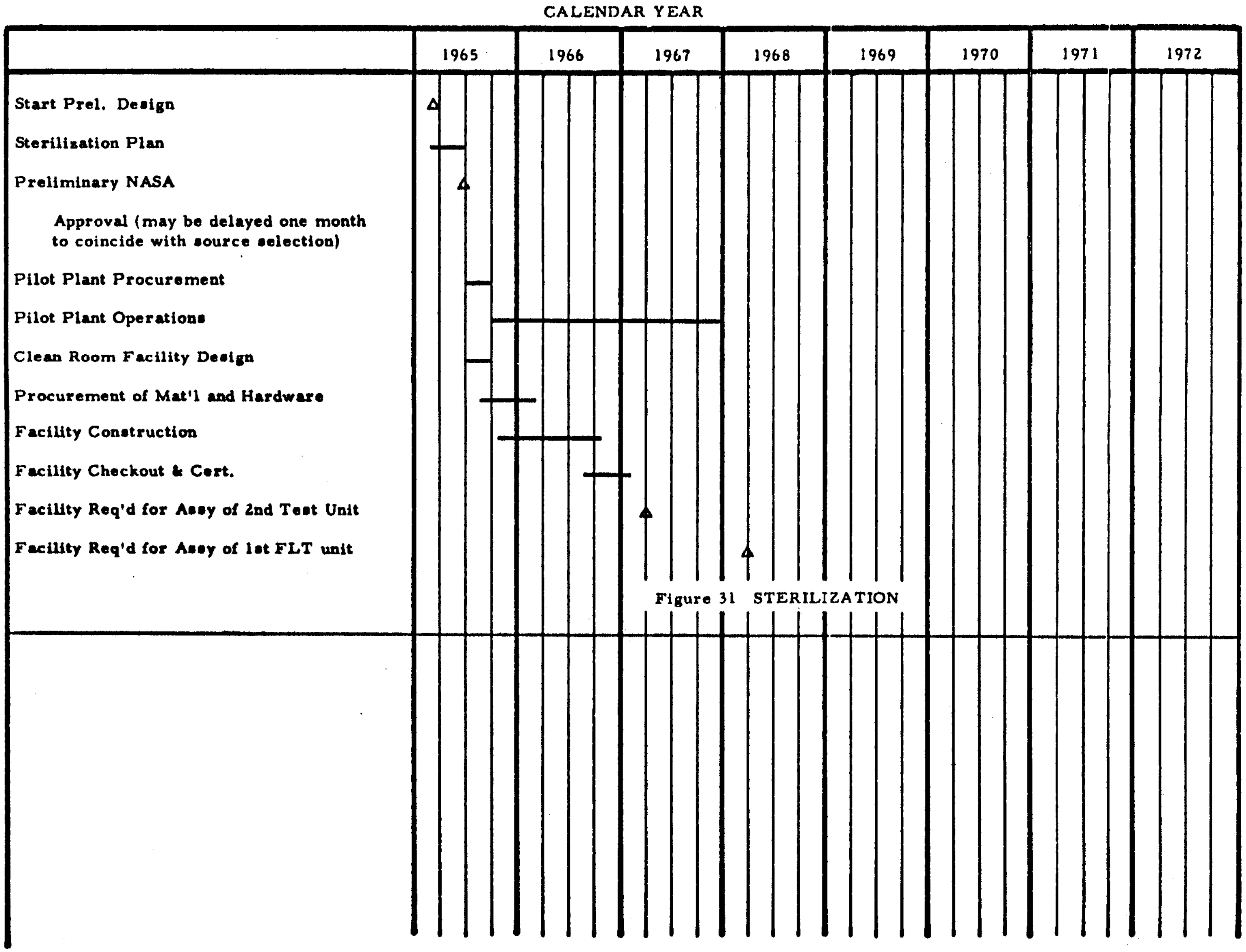


Figure 31 STERILIZATION

RE-ORDER No. 64-525

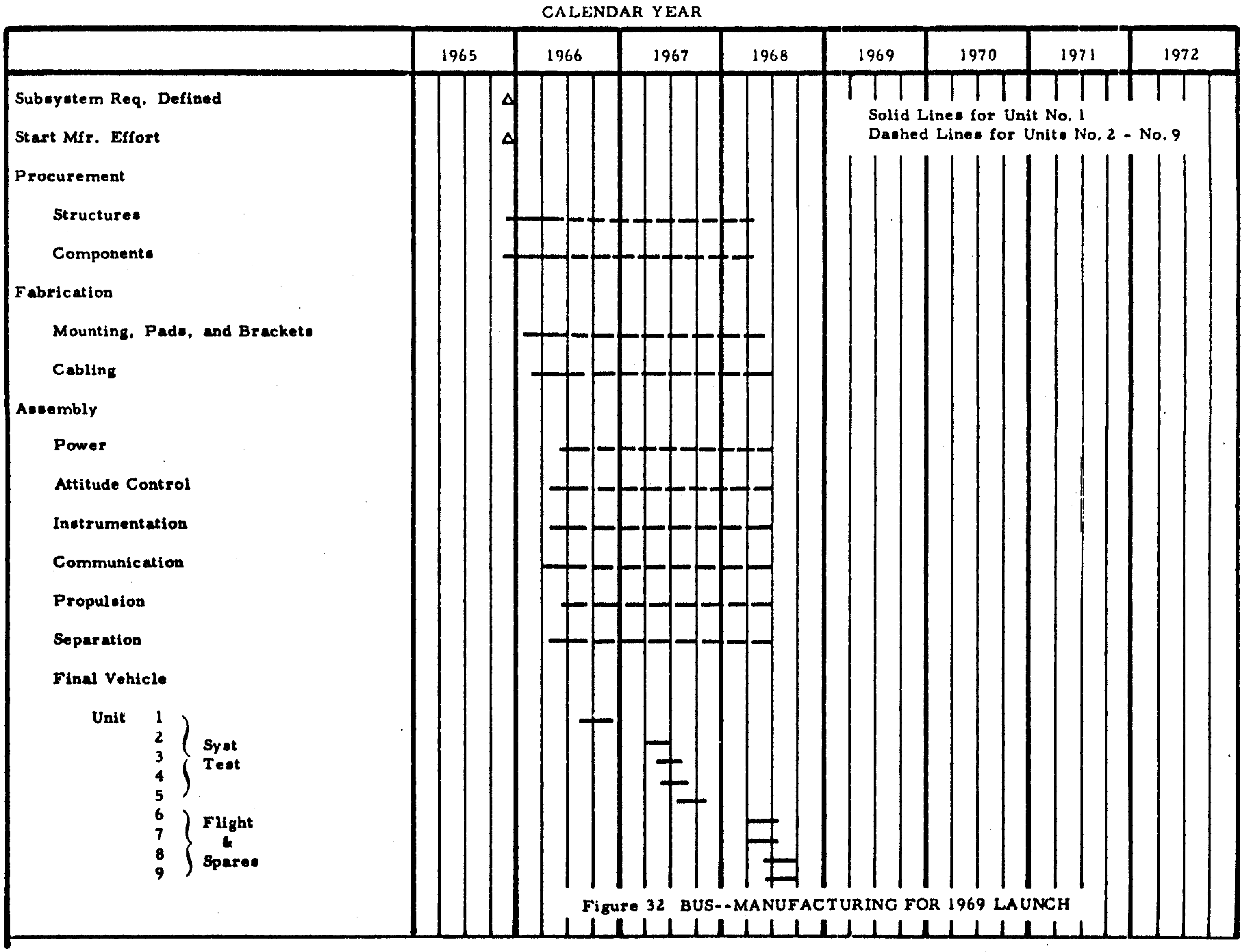


Figure 32 BUS--MANUFACTURING FOR 1969 LAUNCH

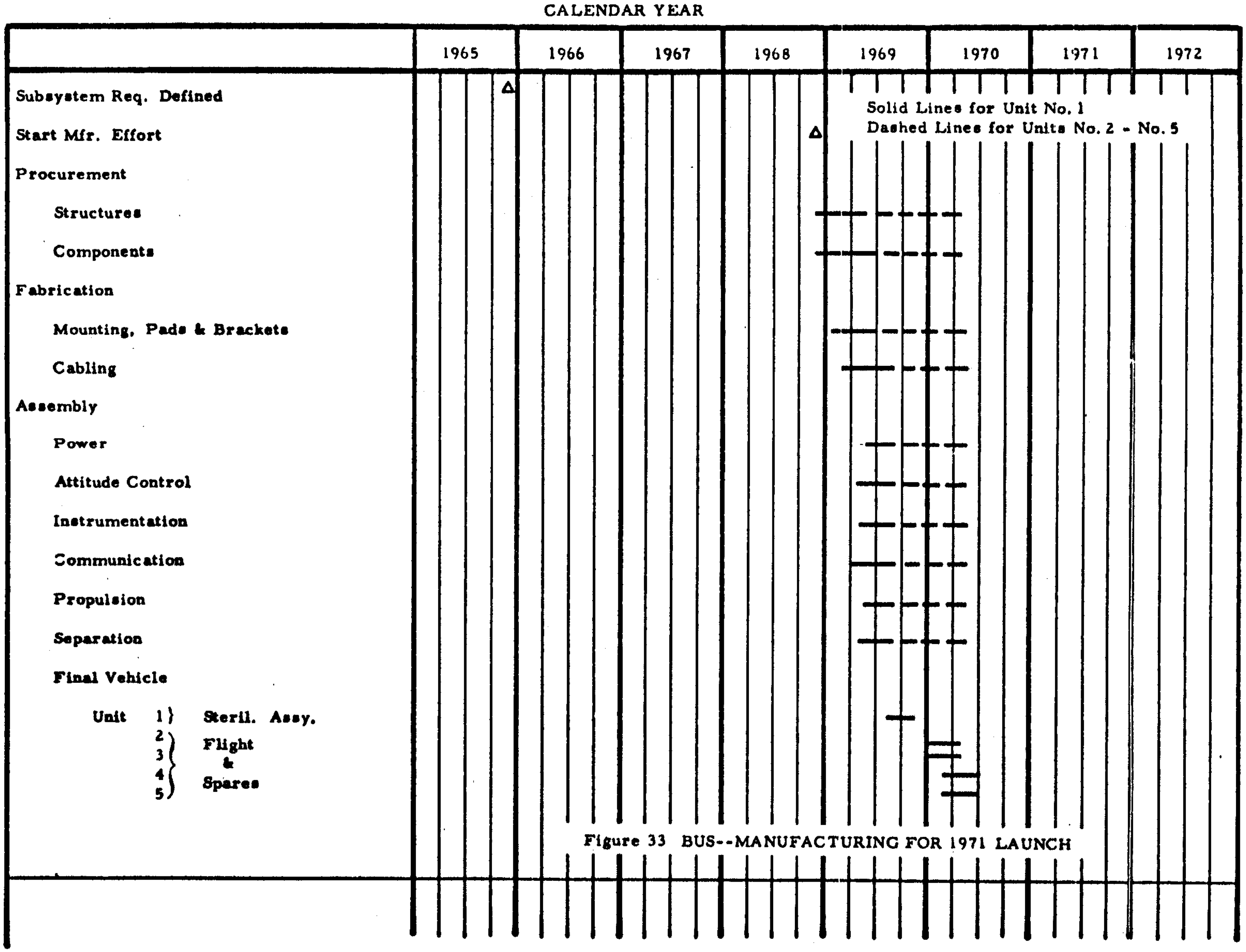


Figure 33 BUS--MANUFACTURING FOR 1971 LAUNCH

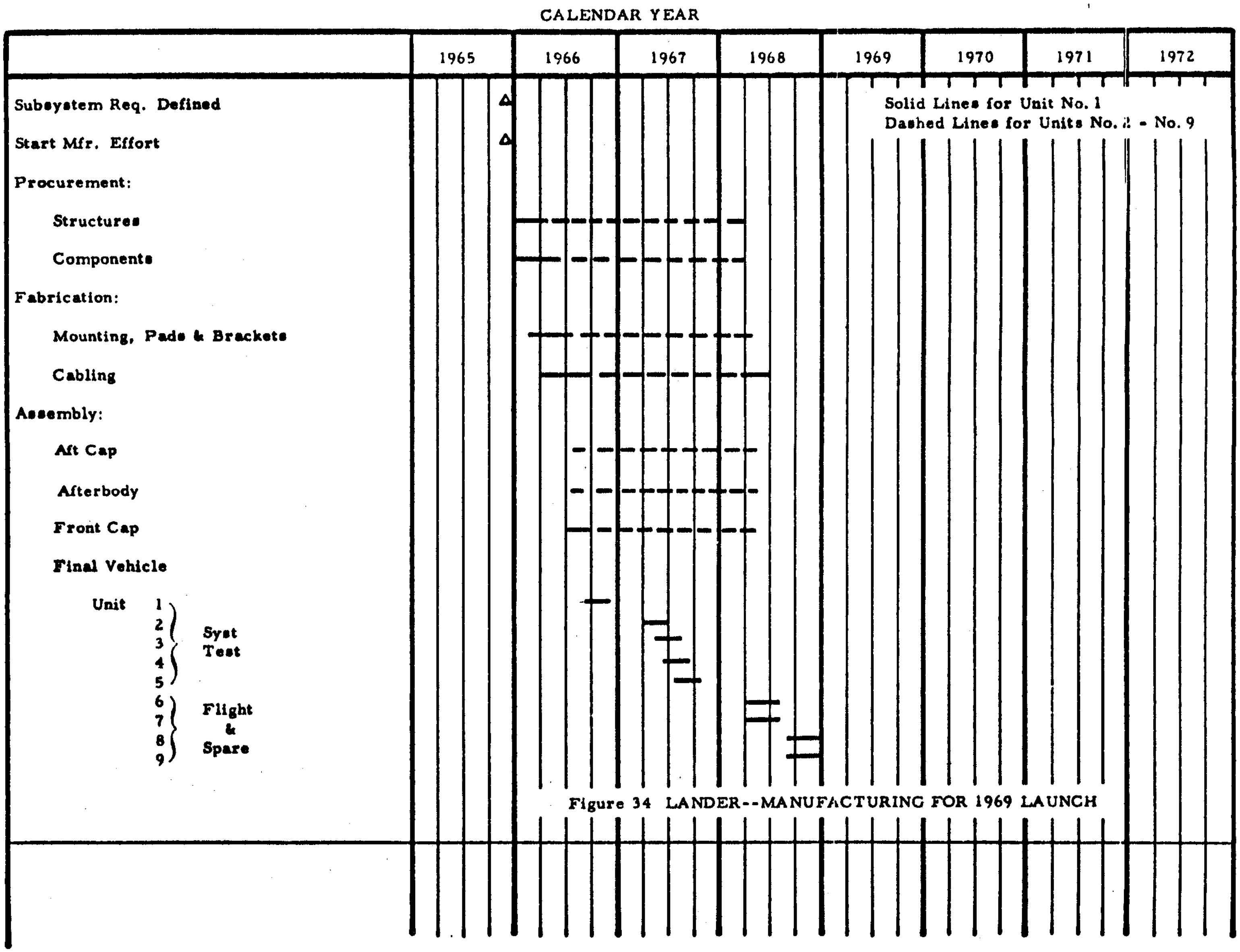


Figure 34 LANDER--MANUFACTURING FOR 1969 LAUNCH

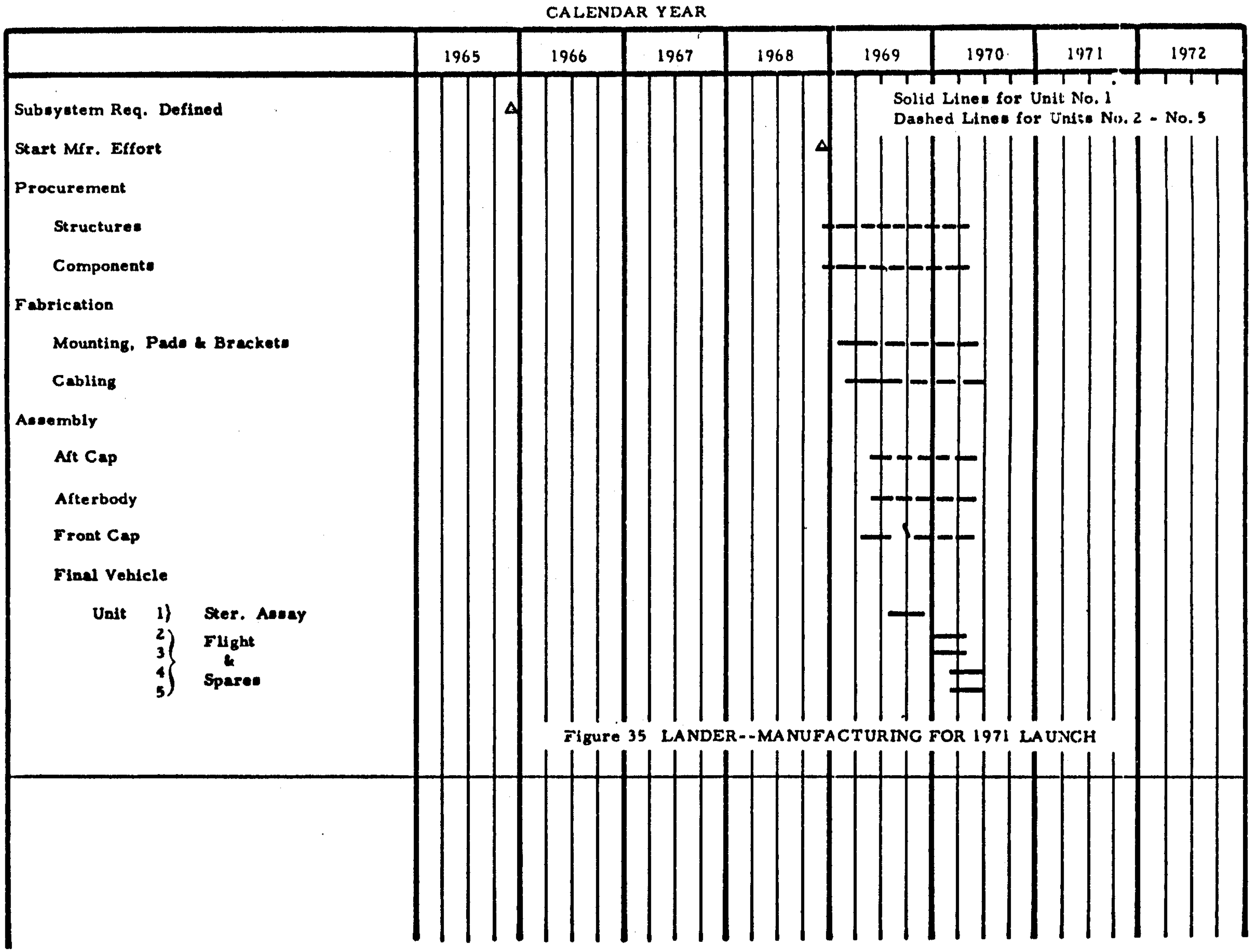


Figure 35 LANDER--MANUFACTURING FOR 1971 LAUNCH

RE-ORDER No. 64-525

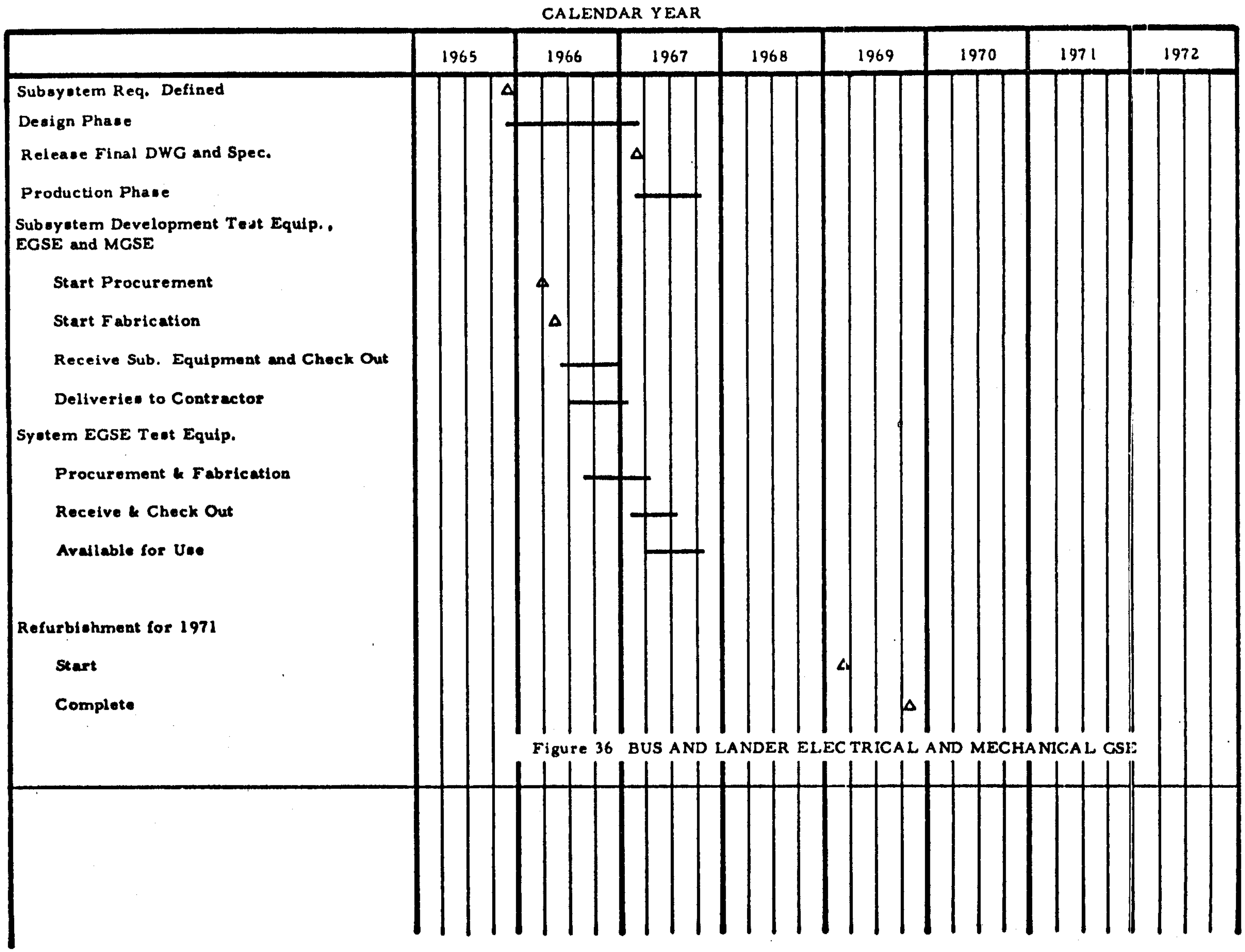


Figure 36 BUS AND LANDER ELECTRICAL AND MECHANICAL GSE

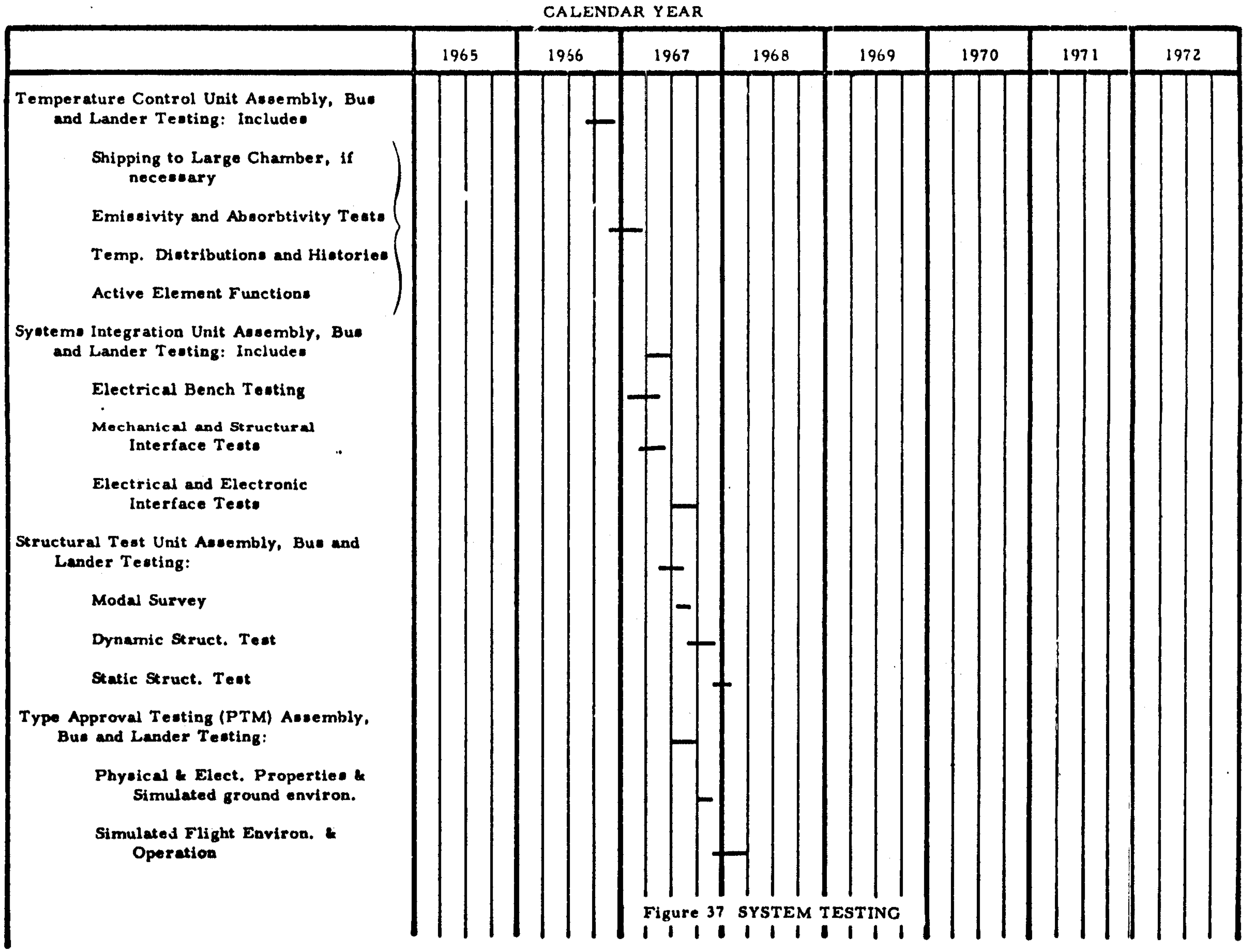


Figure 37 SYSTEM TESTING

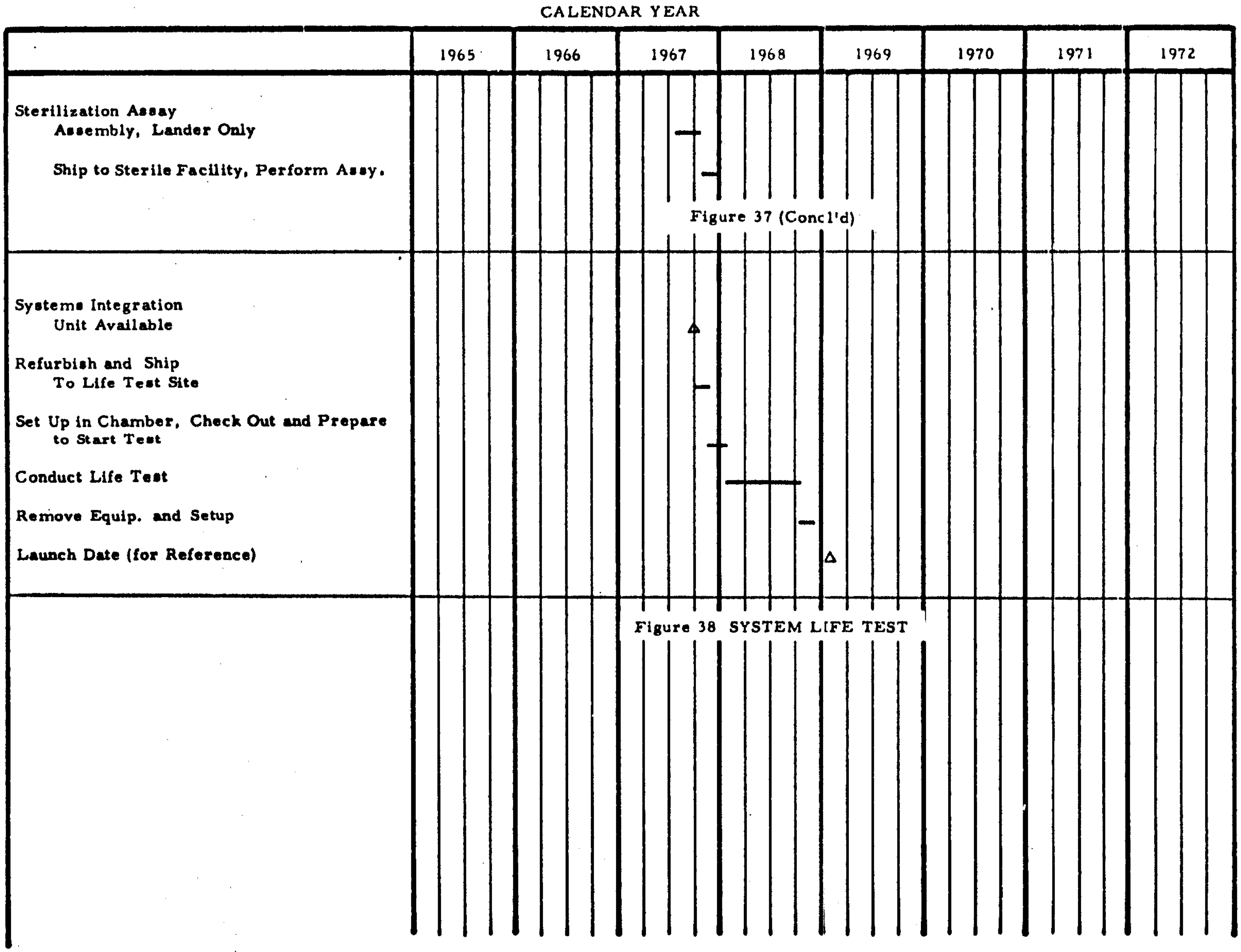


Figure 37 (Concl'd)

Figure 38 SYSTEM LIFE TEST

RE-ORDER No. 64-525

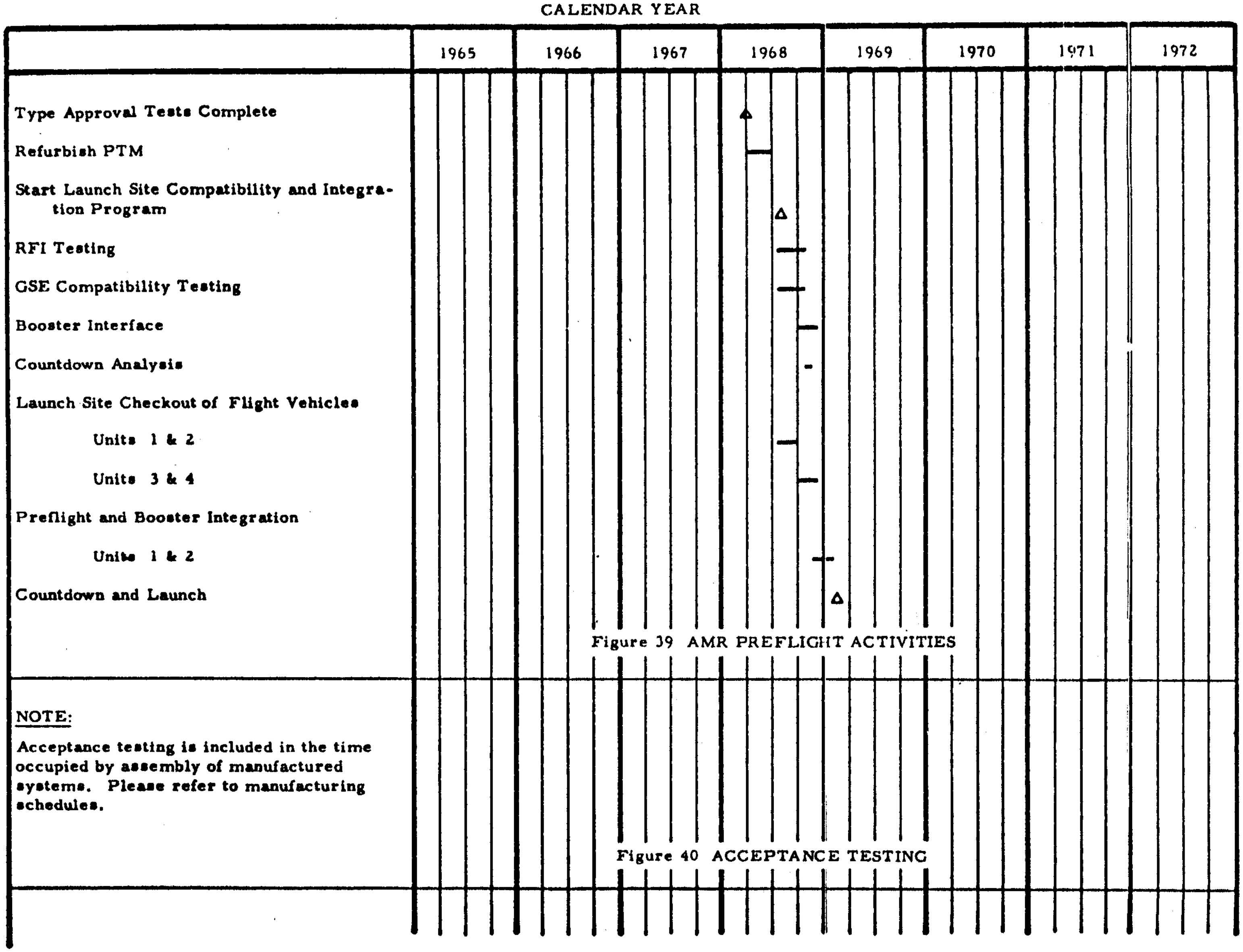


Figure 39 AMR PREFLIGHT ACTIVITIES

Figure 40 ACCEPTANCE TESTING

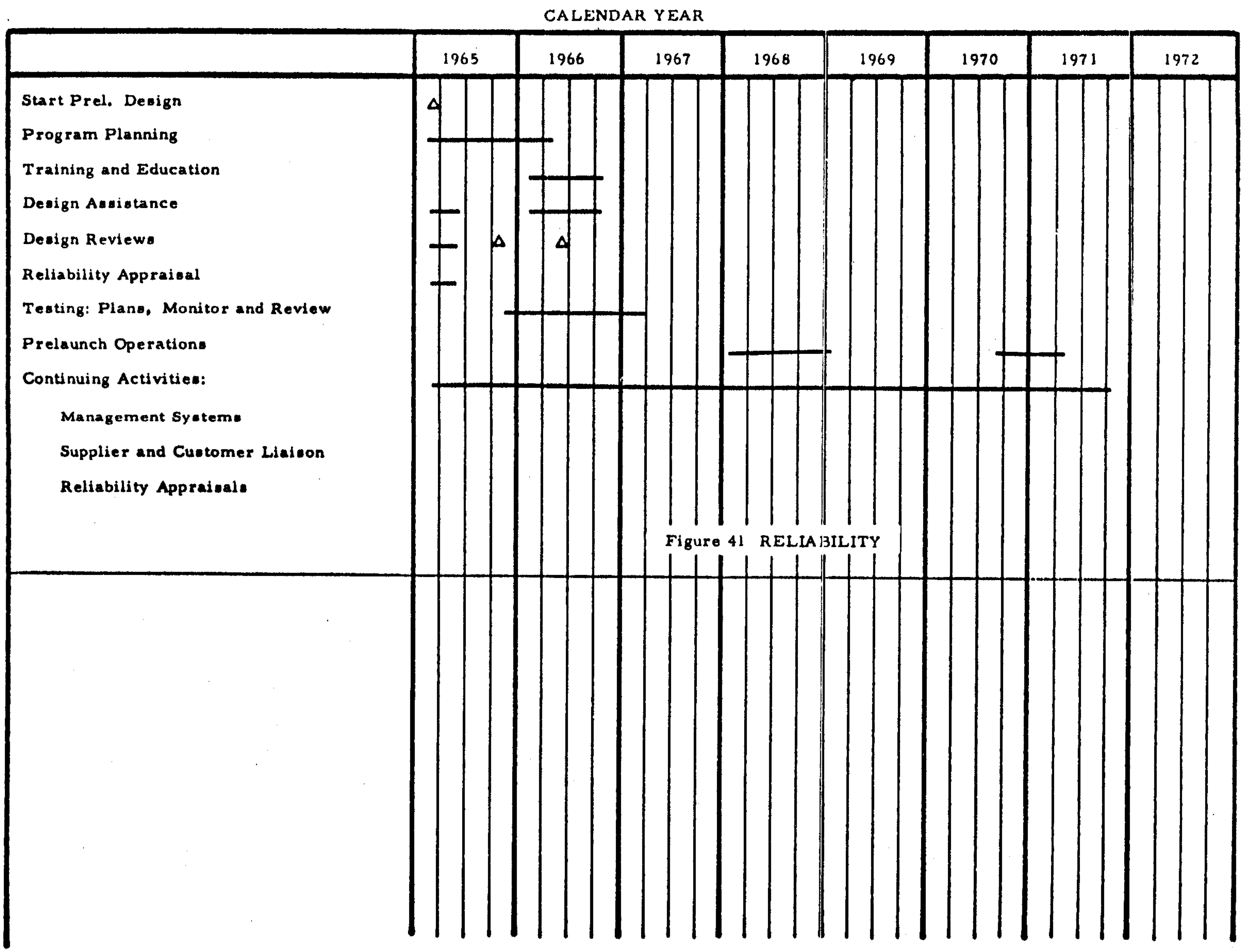


Figure 41 RELIABILITY

RE-ORDER No. 64-525

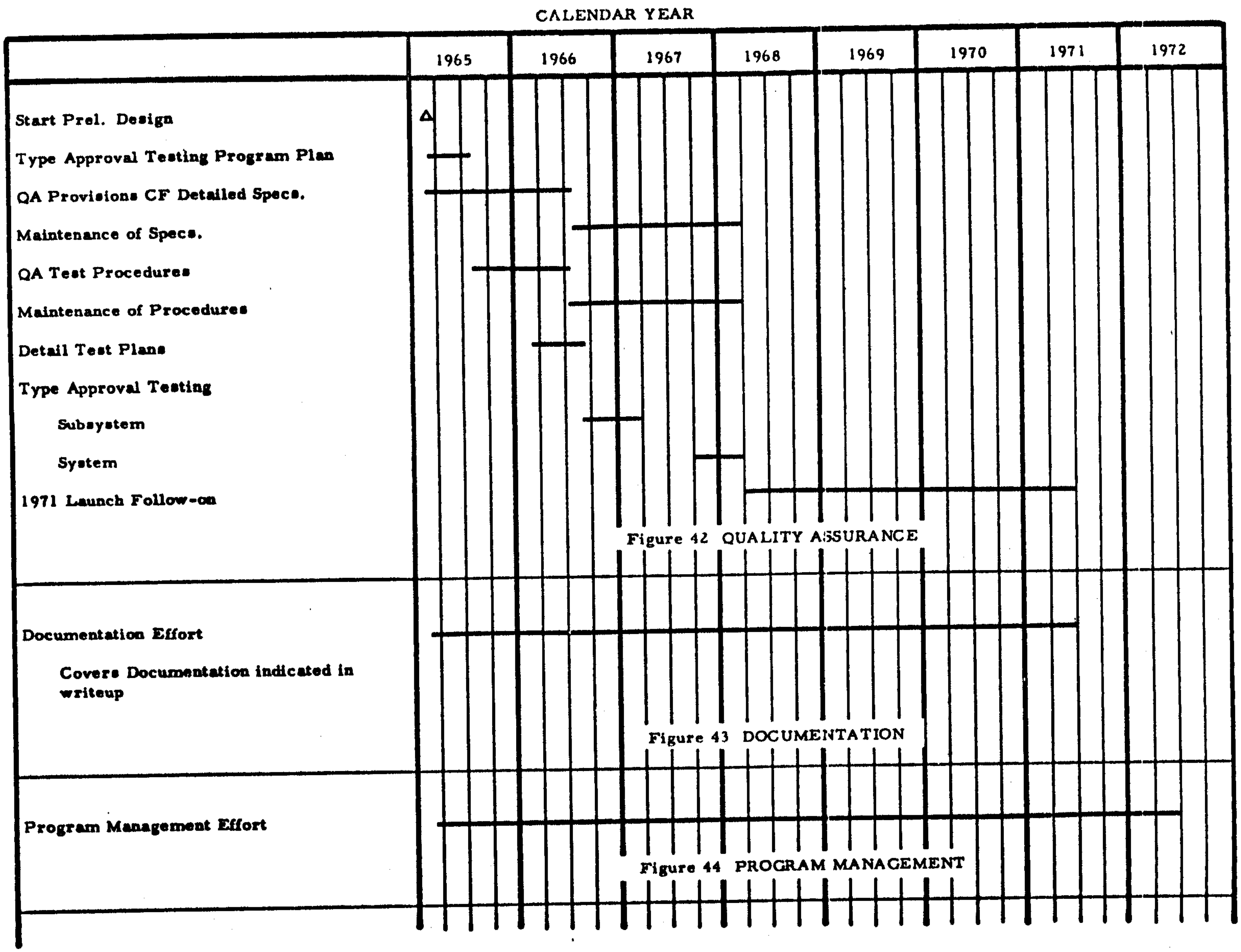


Figure 42 QUALITY ASSURANCE

Figure 43 DOCUMENTATION

Figure 44 PROGRAM MANAGEMENT

This comparison, which is actually the fourth step of the plan development, involves the first of the two problem areas mentioned above--that of the allocation of presently available facilities to meet program needs. If it turns out that a required facility is available in the company, but scheduled for another program, then action must be taken to assure availability of another one for Advanced Mariner. This action could involve either rescheduling the other activity or acquiring a separate capability.

An item-by-item comparison of requirements versus facilities available with regard to anticipated scheduling will generate a preliminary list of any facilities which may be required in addition to those available and will also supplement the loading information on existing facilities to reflect Advanced Mariner impact.

The last step is the one of deciding how the required facility will be acquired. This decision process is essentially the second of two problem areas defined above--acquisition method.

Generally, there are three ways of obtaining a facility capability--buy it, rent it, or subcontract out the portion of work requiring the use of the facility. Each of these possibilities has its attendant problems, and each possibility must be examined in the light of the nature of the facility. For example, it may be quite realistic and even desirable to rent the use of an environmental chamber rather than to build one at great expense of dollars and lead time, possibly thereby jeopardizing the timely completion of the program. On the other hand, from a technical standpoint, it would not be sensible to rent the use of an outside clean room for production or assembly purposes. This would introduce a great many transportation and communications problems which could only be avoided by building the required room in the prime contractor plant.

When each of the items on the list has been examined in this manner, and decisions made about how procurement will be accomplished, who the suppliers and vendors will be and who the construction contractors will be, for example, then the facilities plan will be complete. It will be known then exactly what is required what is available, what the net need is, and how what is needed will be obtained, thereby assuring adequate facilities for the program.

The following list is intended not to be the list resulting from a complete facilities plan as described above, but rather a general list of the more significant facilities required for the Advanced Mariner Program which would not be ordinarily available in spacecraft contractor plants. The list is subdivided into areas of different types of activity.

2.9.1 Subsystem Development

2.9.1.1 Bus Propulsion

A drop tower facility for creating a zero g environment is required to determine performance of the surface tension baffle system to be used for positive expulsion of the propellant.

2.9.1.2 Lander Aerodynamics

Both continuous and blowdown types of wind tunnels will be required for tests at various Mach numbers up to 5.0 in the case of the blowdown tunnel.

2.9.1.3 Lander Thermodynamics and Materials

Arc facilities capable of reproducing the expected entry heating characteristics will be required. These facilities should be capable of performing both shear tests, in which the gas is passed uniformly over the sample surface, and also "splash" tests, in which stagnation data are taken. These facilities should have the capability of reproducing not only convective heating, but also radiative heating.

2.9.1.4 Parachute Subsystem

A rocket testing range will be required for the necessary drogue deployment and deceleration tests. These tests will require all the usual range facilities, plus six instrumented sounding type rockets and associated handling equipment.

A wind tunnel will be required for configuration testing ranging in speed from 0.5 to 4.5 Mach.

Aircraft and associated facilities will be needed to conduct drop tests of the prototype subsystems with a boiler plate lander. Aircraft must be able to perform in excess of 50,000 feet.

2.9.1.5 Impact Attenuation Subsystem

A rocket sled facility is required to perform instrumented impact tests at speeds of 200 ft/sec.

Aircraft and associated facilities will be required to conduct a series of drop tests onto various terrain. Aircraft must be able to operate at low speeds of up to about 200 miles per hour.

2.9.1.6 Sterilization

Clean room facilities for assembly of both subsystems systems are required. The facility is discussed in detail in the Sterilization Section of the plan and need only be briefly mentioned here. This facility should be basically a class 100 clean area, of about 12,000 ft^2 usable area, and contain an oven for terminal heat sterilization, which should be about 20 ft^3. The sterilization oven should be duplicated at the launch site.

This facility should contain within it several items of equipment which while not basically unusual, are considered here because of the requirement that they be usable only in the clean room, since transfer in and out is not practical.

Automatic particle counter.
Pelton-type balancer.
Moment of inertia machine.
Inspection tooling and fixtures.
Miscellaneous inspection and test equipment.

2.9.2 <u>System Development</u>

2.9.2.1 Temperature Control System Test

A space chamber will be needed of sufficient size to accept the entire spacecraft and supporting mounts, but not necessarily with solar panels attached. 10^{-5} torr or less must be maintained, and solar simulation should be available.

2.9.2.2 System Integration and Life Tests

The life test will require the continuous services of a space chamber for nearly the entire year 1968. The chamber should be similar to the one required for temperature control testing, but should, if possible, be able to accept the spacecraft with solar panels extended.

2.9.2.3 Type Approval Test

A large dynamic vibration facility will be needed to simulate launch environment, and a space chamber similar to the above will be required for simulated mission testing.

A centrifuge will be needed to simulate deceleration of the lander into Mars - a capability of 63,000 g pounds will be required.

2.9.2.4 Sterilization Assay

For this effort a sterile facility will be required to disassemble the lander and develop cultures.

2.9.2.5 Flight Hardware

For assembly of flight hardware the same clean room facility and sterilization oven described above will be required.

For prelaunch activities hanger facilities and test support facilities for all the required tests will be needed. Briefly, the tests which must be supported are the following:

All RFI testing.
GSE Compatibility Testing.
Booster Interface Testing.
Flight Vehicle Checkout.
Preflight and Booster Inegration.

RE-ORDER No. 64-525

3.0 COST PLAN

3.1 INTRODUCTION

The purpose of the cost plan is to estimate the cost of doing the things called out in the development plan in the manner that they are planned there and at the times indicated in the schedules. These costs, as well as all the others presented are governed by several ground rules which are indicated in the following list.

THE SINGLE MOST IMPORTANT GROUND RULE FOR COSTING PURPOSES IS THAT NOTHING GOES WRONG. THIS IS NEVER COMPLETELY TRUE, BUT ALLOWS THE READER TO JUDGE THE IMPACT OF TROUBLE BASED ON HIS OWN EXPERIENCE.

Hardware Covered:

Bus, Lander, and Bus/Booster Interface Only.

Number of Units Covered - 1969 Launch.

System Test - Five Vehicles.
Flight - Four Vehicles, (two Flight and Two Spare).

Number of Units Covered - 1971 Launch.

System Test - One Vehicle.
Flight - Four Vehicles (Two Flight and Two Spare).

Subsystem Development is carried out for the 1969 launch but not for the 1971 launch.

Vehicles used in 1971 are, for costing purposes, identical copies of those used in 1969.

Hardware costs are those associated with

The Fabrication and Quality Control of Four Flight Units.
Fabrication and Quality Control of Flight Hardware GSE.
Acceptance Tests of Flight Hardware.
Spacecraft Field Support.

Development costs are all the other program costs and can be classed in three ways:

Costs associated with the five system test units.
Support costs such as

Management
Reliability
Quality Assurance
Documentation
.

Subsystem development costs.

The dollar figures shown are total dollars, defined as including the following:

Direct labor.
Labor overhead
Materials.
Materials handling.
Travel.
Consultants.
Computer time.
General Administration.

Referring to Figure 45, it can be seen that the most expensive single year is 1966, since most of the development activities occur then.

While the 1965 costs may seem high in terms of budgetary considerations, it is noteworthy that most of the costs occur after the start of fiscal year 1966. The only costs occurring earlier are the preliminary design and sterilization planning of the two competing contractors.

Most of the manufacturing costs are incurred in 1967 and 1968; for that reason they are the second two most expensive years.

3.2 SUMMARY COST PLAN

Figures 46 through 60 present summaries of program costs. These costs agree with the schedule shown in figure 45, and include the types of costs defined in the introduction to the cost plan above. The following discussion identifies generally the major elements of cost for each line item shown in the summary cost tabulation.

3.2.1 Cost Category Descriptions

Described below, principally in outline form, are definitions of what significant costs are included in each of the line items shown in figures 46 through 60.

RE-ORDER No. 64-525

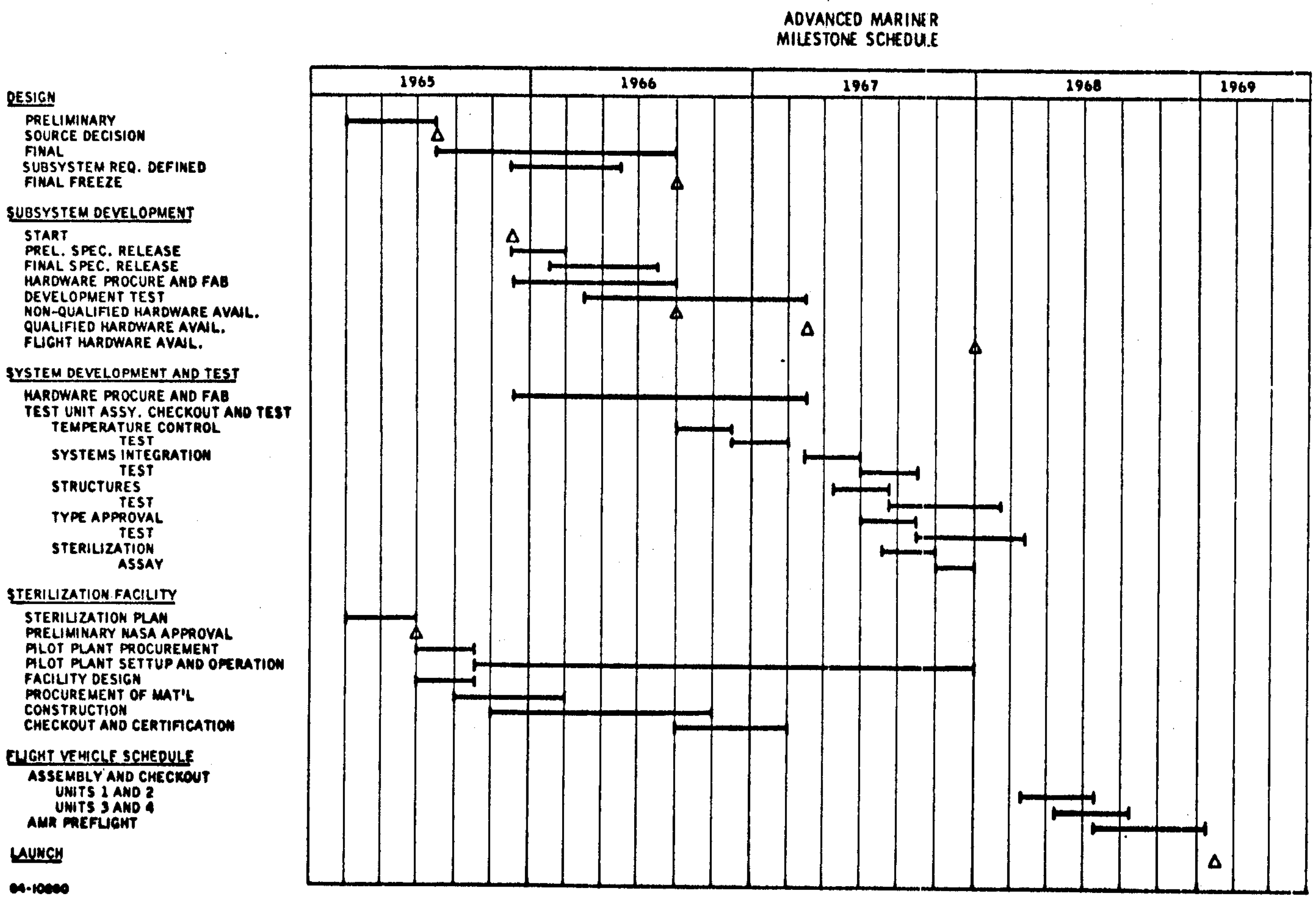


Figure 45 ADVANCED MARINER MILESTONE SCHEDULE

($ x 10^{-3})

CALENDAR YEAR

	1965	1966	1967	1968	1969	1970	1971	1972	Total
Prel. Design	2,397								2,397
Syst. Anal. & Int.		1,344	1,925	2,093	2,067	1,194	1,240	434	11,044
Final Design	2,607	4,710	3,161	1,061	94	54			11,709
Devel. Prog:									
Bus									
TV		1,380	685						2,065
Payload Plat.		405	53	39	10				507
Comm. & Pwr		2,787	437						3,224
Attitude Cont.		1,122	1,320						2,442
Propulsion		2,240	1,600						3,840
Temp. Cont.		330	350	117					797
B/L Sep. Syst.		1,550	580						2,130
Science Liaison		17	17	17					51
Lander:									
Aerodynamics		892							892
Comm. & Pwr		2,663	333						2,996
Structures		548	430						978
Thermo & Mat'l		1,116	420	33	3	3			1,575
Parachute		1,990							1,990
Impact		1,833							1,833
Propulsion		421	421						842
Temp. Cont.		245	155	99					499
Sterilization	2,700	1,800	1,800						6,300
Science Liaison		27	27	26					80
Mfr & Q.C.		11,572	23,404	9,669	16,144	7,092	1,035	68	68,984
GSE		4,956	2,362	1,063	411	108	30		8,930
Syst. Testing:									
Temp. Cont.		236	472	94					802
Syst. Integ.			280	2,255					2,535
Structural			494						494
Type Approval		26	764	112					902
Steril. Assay			429			429			858
Accept. Testing			820	820		820			2,460
Rel. & QA		1,950	2,028	962	344	140	96		5,520
Documentation		192	268	265	108	108	137		1,078
Prog. Mgmt.		146	198	194	188	93	32		851
TOTAL	7,704	47,498	45,233	18,939	19,369	10,790	2,570	502	151,605

Figure 46 1969 & 1971 LAUNCHES - TOTAL SPACECRAFT PROGRAM COST

RE-ORDER No. 64-525

($ x 10⁻³)

CALENDAR YEAR

	1965	1966	1967	1968	1969	1970	1971	1972	Total
Prel. Design	2,397								2,397
Syst. Anal. & Int.		1,344	1,925	1,796	1,249	325			6,639
Final Design	2,607	4,710	3,161	1,081	94	56			11,709
Devel. Prog:									
Bus									
TV		1,380	685						2,065
Payload Plat.		405	53	39	10				507
Comm. & Pwr		2,787	437						3,224
Attitude Cont.		1,122	1,320						2,442
Propulsion		2,240	1,600						3,840
Temp. Cont.		330	350	117					797
B/L Sep. Syst.		1,550	580						2,130
Science Liaison		17	17	17					51
Lander:									
Aerodynamics		892							892
Comm. & Pwr		2,663	333						2,996
Structures		548	430						978
Thermo & Mat'l		1,116	420	33	3	3			1,575
Parachute		1,990							1,990
Impact		1,833							1,833
Propulsion		421	421						842
Temp. Cont.		245	155	99					499
Sterilization	2,700	1,800	1,800						6,300
Science Liaison		27	27	26					80
Mfr & Q.C.		11,572	23,404	8,288	821				44,085
GSE		4,956	2,362	1,063	184				8,565
Syst. Testing:									
Temp. Cont.		236	472	94					802
Syst. Integ.			280	2,255					2,535
Structural			494						494
Type Approval		26	764	112					902
Steril. Assay			429						429
Accept. Testing			820	820					1,640
Rel. & QA		1,950	2,028	858	138	4			4,978
Documentation		192	268	265					725
Prog. Mgmt.		146	198	115	32				491
TOTAL	7,704	46,498	45,233	17,078	2,531	388			119,432

Figure 47 1969 LAUNCH - TOTAL SPACECRAFT PROGRAM COST

($ x 10^{-3})

CALENDAR YEAR

	1965	1966	1967	1968	1969	1970	1971	1972	Total
Prel. Design	N/A								
Syst. Anal. & Int.				297	818	1,616	1,240	434	4,405
Final Design	N/A								
Devel. Prog:									
Bus									
TV									
Payload Plat.									
Comm. & Pwr.									
Attitude Cont.									
Propulsion									
Temp. Cont.									
B/L Sep. Syst.									
Science Liaison		N/A							
Lander:									
Aerodynamics									
Comm. & Pwr									
Structures									
Thermo & Mat'l									
Parachute									
Impact									
Propulsion									
Temp. Cont.									
Sterilization									
Science Liaison									
Mfr & Q.C.				1,381	15,323	7,092	1,035	68	24,899
GSE					227	108	30		365
Syst. Testing:									
Temp. Cont.									
Syst. Integ.	N/A								
Structural									
Type Approval									
Steril. Assay						429			429
Accept. Testing						820			820
Rel. & QA				104	206	136	96		542
Documentation					108	108	137		353
Prog. Mgmt.				79	156	93	32		360
TOTAL				1,861	16,838	10,402	2,570	502	32,173

Figure 48 1971 LAUNCH--TOTAL SPACECRAFT PROGRAM COST

RE-ORDER No. 64-525

($\$ \times 10^{-3}$)

CALENDAR YEAR

	1965	1966	1967	1968	1969	1970	1971	1972	Total
Prel. Design	1,606								1,606
Syst. Anal. & Int.		748	1,040	1,175	723	140			3,826
Final Design	1,816	2,070	1,520	795					6,201
Devel. Prog:									
Bus									
TV		1,380	685						2,065
Payload Plat.		405	53	39	10				507
Comm. & Pwr		2,787	437						3,224
Attitude Cont.		1,122	1,320						2,442
Propulsion		2,240	1,600						3,840
Temp. Cont.		330	350	117					797
B/L Sep. Syst.		1,550	580						2,130
Science Liaison		17	17	17					51
Lander:									
Aerodynamics									
Comm. & Pwr									
Structures									
Thermo & Mat'l									
Parachute									
Impact									
Propulsion									
Temp. Cont.									
Sterilization									
Science Liaison									
Mfr & Q. C.		8,156	16,874	5,217	458				30,705
GSE		2,980	1,270	532	92				4,874
Syst. Testing:									
Temp. Cont.		197	397	65					659
Syst. Integ.			187	1,505					1,692
Structural			250						250
Type Approval		14	420	63					497
Steril. Assay									
Accept. Testing			510	510					1,020
Rel. & QA		1,237	1,296	553	106	2			3,194
Documentation		86	123	123					332
Prog. Mgmt.		63	85	49	14				211
TOTAL	3,422	25,382	29,014	10,760	1,403	142			70,123

Figure 49 1969 LAUNCH--BUS TOTAL COST

RE-ORDER No. 64-525

($ x 10⁻³)

CALENDAR YEAR

	1965	1966	1967	1968	1969	1970	1971	1972	Total
Prel. Design	791								791
Syst. Anal. & Int.		596	885	621	526	185			2,813
Final Design	791	2,640	1,641	286	94	56			5,508
Devel. Prog:									
Bus									
TV									
Payload Plat.									
Comm. & Pwr									
Attitude Cont.		N/A							
Propulsion									
Temp. Cont.									
B/L Sep. Syst.									
Science Liaison									
Lander:									
Aerodynamics		892							892
Comm. & Pwr		2,663	333						2,996
Structures		548	430						978
Thermo & Mat'l		1,116	420	33	3	3			1,575
Parachute		1,990							1,990
Impact		1,833							1,833
Propulsion		421	421						842
Temp. Cont.		245	155	99					499
Sterilization	2,700	1,800	1,800						6,300
Science Liaison		27	27	26					80
Mfr & Q.C.		3,416	6,530	3,071	363				13,380
GSE		1,976	1,092	531	92				3,691
Syst. Testing:									
Temp. Cont.		39	75	29					143
Syst. Integ.			93	750					843
Structural			244						244
Type Approval		12	344	49					405
Steril. Assay			429						429
Accept. Testing			310	310					620
Rel. & QA		713	732	305	32	2			1,784
Documentation		106	145	142					393
Prog. Mgmt.		83	113	66	18				280
TOTAL	4,282	21,116	16,219	6,318	1,128	246			49,309

Figure 50 1969 LAUNCH--LANDER TOTAL COST

($ x 10^{-3})

CALENDAR YEAR

	1965	1966	1967	1968	1969	1970	1971	1972	Total
Prel. Design	N/A								
Syst. Anal. & Int.				142	425	990	775	210	2,542
Final Design	N/A								
Devel. Prog:									
Bus									
TV									
Payload Plat.									
Comm. & Pwr									
Attitude Cont.									
Propulsion									
Temp. Cont.									
B/L Sep. Syst.									
Science Liaison									
Lander:		N/A							
Aerodynamics									
Comm. & Pwr									
Structures									
Thermo & Mat'l									
Parachute									
Impact									
Propulsion									
Temp. Cont.									
Sterilization									
Science Liaison									
Mfr & Q.C.				1,202	11,183	4,687	569	42	17,683
GSE					204	90	21		315
Syst. Testing:									
Temp. Cont.									
Syst. Integ.									
Structural		N/A							
Type Approval									
Steril. Assay									
Accept. Testing						510			510
Rel. & QA				54	100	69	49		272
Documentation					70	70	90		230
Prog. Mgmt.				35	70	41	14		160
TOTAL				1,433	12,052	6,457	1,518	252	21,712

Figure 51 1971 LAUNCH--BUS TOTAL COST

RE ORDER No 64-525

($ x 10^-3)

CALENDAR YEAR

	1965	1966	1967	1968	1969	1970	1971	1972	Total
Prel. Design	N/A								
Syst. Anal. & Int.				155	393	626	465	224	1,863
Final Des'gn	N/A								
Devel. Prog:									
Bus									
TV									
Payload Plat.									
Comm. & Pwr									
Attitude Cont.									
Propulsion									
Temp. Cont.									
B/L Sep. Syst.									
Science Liaison									
Lander:		N/A							
Aerodynamics									
Comm. & Pwr									
Structures									
Thermo & Mat'l									
Parachute									
Impact									
Propulsion									
Temp. Cont.									
Sterilization									
Science Liaison									
Mfr & Q.C.				179	4,140	2,405	466	26	7,216
GSE					23	18	9		50
Syst. Testing:									
Temp. Cont.									
Syst. Integ.		N/A							
Structural									
Type Approval									
Steril. Assay						429			429
Accept. Testing						310			310
Rel. & QA				50	106	67	47		270
Documentation					38	38	47		123
Prog. Mgmt.				44	86	52	18		200
TOTAL				428	4,786	3,945	1,052	250	10,461

Figure 52 1971 LAUNCH--LANDER TOTAL COST

($\$ \times 10^{-3}$)

CALENDAR YEAR

	1965	1966	1967	1968	1969	1970	1971	1972	Total
Prel. Design	1,606								1,606
Syst. Anal. & Int.		411	571	646	379	77			2,102
Final Design	1,816	2,070	1,520	795					6,201
Devel. Prog:									
Bus									
TV		1,380	685						2,065
Payload Plat.		405	53	39	10				507
Comm. & Pwr		2,787	437						3,224
Attitude Cont.		1,122	1,320						2,442
Propulsion		2,240	1,600						3,840
Temp. Cont.		330	350	117					797
B/L Sep. Syst.		1,550	580						2,130
Science Liaison		17	17	17					51
Lander:									
Aerodynamics									
Comm. & Pwr									
Structures									
Thermo & Mat'l		N/A							
Parachute									
Impact									
Propulsion									
Temp. Cont.									
Sterilization									
Science Liaison									
Mfr & Q.C.		4,488	9,248	2,864	248				16,848
GSE		2,390	1,018	426	74				3,908
Syst. Testing:									
Temp. Cont.		197	397	65					659
Syst. Integ.			187	1,505					1,692
Structural			250						250
Type Approval		14	420	63					497
Steril. Assay	N/A								
Accept. Testing			280	280					560
Rel. & QA		1,237	1,296	553	106	2			3,194
Documentation		86	123	123					332
Prog. Mgmt.		63	85	49	14				211
TOTAL	3,422	20,787	20,437	7,542	849	79			53,116

Figure 53 1969 LAUNCH--BUS DEVELOPMENT

RE-ORDER No. 64-525

($ x 10^-3)

CALENDAR YEAR

	1965	1966	1967	1968	1969	1970	1971	1972	Total
Prel. Design	N/A								
Syst. Anal. & Int.		337	469	529	326	63			1,724
Final Design	N/A								
Devel. Prog:									
Bus									
TV									
Payload Plat.									
Comm. & Pwr									
Attitude Cont.									
Propulsion									
Temp. Cont.									
B/L Sep. Syst.									
Science Liaison									
Lander:		N/A							
Aerodynamics									
Comm. & Pwr									
Structures									
Thermo & Mat'l									
Parachute									
Impact									
Propulsion									
Temp. Cont.									
Sterilization									
Science Liaison									
Mfr & Q. C.		3,668	7,626	2,353	210				13,857
GSE		590	252	106	18				966
Syst. Testing:									
Temp. Cont.									
Syst. Integ.	N/A								
Structural									
Type Approval									
Steril. Assay									
Accept. Testing			230	230					460
Rel. & QA									
Documentation	N/A								
Prog. Mgmt.									
TOTAL		4,595	8,577	3,218	554	63			17,007

Figure 54 1969 LAUNCH--BUS HARDWARE COST

RE-ORDER No. 64525

($ x 10^{-3})

CALENDAR YEAR

	1965	1966	1967	1968	1969	1970	1971	1972	Total
Prel. Design	791								791
Syst. Anal. & Int.		328	487	341	289	102			1,547
Final Design	791	2,640	1,641	286	94	56			5,508
Devel. Prog:									
Bus									
TV									
Payload Plat.									
Comm. & Pwr									
Attitude Cont.	N/A								
Propulsion									
Temp. Cont.									
B/L Sep. Syst.									
Science Liaison									
Lander:									
Aerodynamics		892							892
Comm. & Pwr		2.663	333						2,996
Structures		548	430						978
Thermo & Mat'l		1,116	420	33	3	3			1,575
Parachute		1,990							1,990
Impact		1,833							1,833
Propulsion		421	421						842
Temp. Cont.		245	155	99					499
Sterilization	2,700	1,800	1,800						6,300
Science Liaison		27	27	26					80
Mfr & Q.C.		1,876	3,589	1,692	200				7,357
GSE		1,630	900	438	76				3,044
Syst. Testing:									
Temp. Cont.		39	75	29					143
Syst. Integ.			93	750					843
Structural			244						244
Type Approval		12	344	49					405
Steril. Assay			429						429
Accept. Testing			170	170					340
Rel. & QA		713	732	305	32	2			1,784
Documentation		106	145	142					393
Prog. Mgmt.		83	113	66	18				280
TOTAL	4,282	18,962	12,548	4,426	712	163			41,093

Figure 55 1969 LAUNCH--LANDER DEVELOPMENT

RE-ORDER No. 64-525

($ x 10^-3)

CALENDAR YEAR

	1965	1966	1967	1968	1969	1970	1971	1972	Total
Prel. Design	N/A								
Syst. Anal. & Int.		268	398	280	237	83			1,266
Final Design	N/A								
Devel. Prog:									
Bus									
TV									
Payload Plat.									
Comm. & Pwr									
Attitude Cont.									
Propulsion									
Temp. Cont.									
B/L Sep. Syst.									
Science Liaison		N/A							
Lander:									
Aerodynamics									
Comm. & Pwr									
Structures									
Thermo & Mat'l									
Parachute									
Impact									
Propulsion									
Temp. Cont.									
Sterilization									
Science Liaison									
Mfr & Q.C.		1,540	2,941	1,379	163				6,023
GSE		346	192	93	16				647
Syst. Testing:									
Temp. Cont.									
Syst. Integ.	N/A								
Structural									
Type Approval									
Steril. Assay									
Accept. Testing			140	140					280
Rel. & QA									
Documentation	N/A								
Prog. Mgmt.									
TOTAL		2,154	3,671	1,892	416	83			8,216

Figure 56 1969 LAUNCH--LANDER HARDWARE COST

RE-ORDER No. 64-525

($ x 10^-3)

CALENDAR YEAR

	1965	1966	1967	1968	1969	1970	1971	1972	Total
Prel. Design	N/A								
Syst. Anal. & Int.				78	234	544	426	115	1,397
Final Design	N/A								
Devel. Prog:									
Bus									
TV									
Payload Plat.									
Comm. & Pwr									
Attitude Cont.									
Propulsion									
Temp. Cont.									
B/L Sep. Syst.									
Science Liaison									
Lander:		N/A							
Aerodynamics									
Comm. & Pwr									
Structures									
Thermo & Mat'l									
Parachute									
Impact									
Propulsion									
Temp. Cont.									
Sterilization									
Science Liaison									
Mfr & Q.C.				238	2,028	937	114	8	3,325
GSE					41	18	4		63
Syst. Testing:									
Temp. Cont.									
Syst. Integ.									
Structural	N/A								
Type Approval									
Steril. Assay									
Accept. Testing						102			102
Rel. & QA				54	100	69	49		272
Documentation					70	70	90		230
Prog. Mgmt.				35	70	41	14		160
TOTAL				405	2,543	1,781	697	123	5,549

Figure 57 1971 LAUNCH--BUS DEVELOPMENT COST

($\$ \times 10^{-3}$)

CALENDAR YEAR

	1965	1966	1967	1968	1969	1970	1971	1972	Total
Prel. Design	N/A								
Syst. Anal. & Int.				64	191	446	349	95	1,145
Final Des'gn	N/A								
Devel. Prog:									
Bus									
TV									
Payload Plat.									
Comm. & Pwr									
Attitude Cont.									
Propulsion									
Temp. Cont.									
B/L Sep. Syst.									
Science Liaison									
Lander:		N/A							
Aerodynamics									
Comm. & Pwr									
Structures									
Thermo & Mat'l									
Parachute									
Impact									
Propulsion									
Temp. Cont.									
Sterilization									
Science Liaison									
Mfr & Q.C.				964	9,155	3,750	455	34	14,358
GSE					163	72	17		252
Syst. Testing:									
Temp. Cont.									
Syst. Integ.									
Structural	N/A								
Type Approval									
Steril. Assay									
Accept. Testing						408			408
Rel. & QA									
Documentation	N/A								
Prog. Mgmt.									
TOTAL				1,028	9,509	4,676	821	129	16,163

Figure 58 1971 LAUNCH--BUS HARDWARE COST

RE-ORDER No. 64-5

($ x 10^-3)

CALENDAR YEAR

	1965	1966	1967	1968	1969	1970	1971	1972	Total
Prel. Design	N/A								
Syst. Anal. & Int.				85	216	344	256	123	1,024
Final Design	N/A								
Devel. Prog:									
Bus									
TV									
Payload Plat.									
Comm. & Pwr									
Attitude Cont.									
Propulsion									
Temp. Cont.									
B/L Sep. Syst.									
Science Liaison									
Lander:		N/A							
Aerodynamics									
Comm. & Pwr									
Structures									
Thermo & Mat'l									
Parachute									
Impact									
Propulsion									
Temp. Cont.									
Sterilization									
Science Liaison									
Mfr & Q.C.				35	723	480	93	5	1,336
GSE					5	4	2		11
Syst. Testing:									
Temp. Cont.									
Syst. Integ.		N/A							
Structural									
Type Approval									
Steril. Assay						429			429
Accept. Testing						62			62
Rel. & QA				50	106	67	47		270
Documentation					38	38	47		123
Prog. Mgmt.				44	86	52	18		200
TOTAL				214	1,174	1,476	463	128	3,455

Figure 59 1971 LAUNCH--LANDER DEVELOPMENT COST

RE-ORDER No. 64-525

($ x 10^-3)

CALENDAR YEAR

	1965	1966	1967	1968	1969	1970	1971	1972	Total
Prel. Design	N/A								
Syst. Anal. & Int.				70	177	282	209	101	839
Final Design	N/A								
Devel. Prog:									
Bus									
TV									
Payload Plat.									
Comm. & Pwr									
Attitude Cont.									
Propulsion									
Temp. Cont.									
B/L Sep. Syst.									
Science Liaison									
Lander:		N/A							
Aerodynamics									
Comm. & Pwr									
Structures									
Thermo & Mat'l									
Parachute									
Impact									
Propulsion									
Temp. Cont.									
Sterilization									
Science Liaison									
Mfr & Q.C.				144	3,417	1,925	373	21	5,880
GSE					18	14	7		39
Syst. Testing:									
Temp. Cont.									
Syst. Integ.	N/A								
Structural									
Type Approval									
Steril. Assay									
Accept. Testing						248			248
Rel. & QA									
Documentation	N/A								
Prog. Mgmt.									
TOTAL				214	3,612	2,469	589	122	7,006

Figure 60 1971 LAUNCH--LANDER HARDWARE COST

a. Preliminary Design - Includes the efforts of two competing contractor candidates, each employing teams of 70 to 80 men, and involving travel, consultants, and computer time.

b. System Analysis, Integration, and Field Support

The peak effort, occurring in 1968, involves a level of over 60 prime contractor people for all these responsibilities. Computer time is for trajectory analyses and special test equipment is required for the system integration and life tests.

c. Final Design

This effort involves the activities only of the winning contractor, and includes labor at about the same level as for preliminary design. This cost, however, also includes testing for design support, particularly for the bus, the structure of which is not considered as a separate subsystem development program, but rather as a hardware product associated directly with the system design effort. This structure is considered fairly straightforward, and so for purposes of this plan, was included in the final design effort.

d. Bus Television Subsystem

This development effort is based on a peak man loading of four prime contractor men. Development materials, special test equipment, and subcontracts amount to about half the cost.

e. Bus Payload Platform

The peak prime contractor effort for this subsystem program requires a loading of about 10 men. Materials and subcontracts are relatively low, requiring only about 20 percent of the total cost.

f. Bus Communication and Power

In 1966 the peak prime contractor manpower requirement here is about 46. Computer costs are fairly minor, while subcontract costs amount to about 40 percent of the total.

g. Bus Attitude Control

This estimate includes the efforts for both the reaction control subsystem, which slows the bus down after lander separation, and the attitude control subsystem. The peak prime contractor manpower requirement is about 30 men, and materials and subcontracts amount to less than 20 percent.

RE-ORDER No. 64-525

h. Bus Propulsion

This effort requires a level on only about 4 prime contractor men, but the subcontract costs are high and amount to nearly 70 percent of the cost.

i. Bus Temperature Control

A six-man prime contractor loading is required for this program. Subcontractor costs are over 50 percent of the cost because of the assumption of outside rental of a large space chamber.

j. Bus-Lander separation

In addition to the peak manpower level of about 30, the cost is made up of development materials and special test equipment to conduct five separate types of tests--separation mechanism, spin rockets, sterilization canister jettison, lander retrorocket jettison, and yo-yo despin release.

k. Bus Scientific Liaison

This activity is basically one of communication and will occupy about half the time of the man responsible.

l. Lander Aerodynamics

About half this cost is prime contractor personnel loaded to a level of about 20. The remaining costs are basically wind tunnel and computer rentals.

m. Lander Communication and Power

About 40 prime contractor personnel are required for this effort, with about half the costs being incurred by subcontracts for S-band power amplifiers and exciters, data handling subsystems, NiCad battery, and plated wire memory.

n. Lander Structures

In addition to the final design effort, the subsystem program will require a peak of about 10 men, in addition to materials and special test equipment.

o. Lander Thermodynamics and Materials

This dual purpose program will require a peak of about 18 men in addition to materials and special test equipment. Subcontract cost estimates are small, for rental of test facilities not expected to be available at the prime contractor.

p. Lander Parachute

The prime contractor requirement is for about 10 men, including materials and special test equipment, while the subcontract costs of about one third are for wind tunnel and rocket sled expenses.

q. Lander Impact

The basic manpower effort required is eight men. Subcontract costs cover performance of air drop tests and sled tests, and the remaining costs are for materials and special test equipment - both prime and subcontractor costs.

r. Lander Temperature Control

About 4 men are required for this effort, the remaining costs being estimated for development hardware and space chamber rental as a subcontract.

s. Lander Sterilization

Essentially four types of costs are estimated here: planning in 1965, which involves the two competing contractors; acquisition of the sterilization pilot plant; operation of the pilot plant through 1967, including all personnel and supplies, and also all the spacecraft components required for sampling in developing the statistical assurance of lander sterility; last, the costs of supervising and monitoring acquisition of the clean room facility and sterilization ovens. The cost of this facility itself, however, is not included.

t. Lander Scientific Liaison

This effort will occupy about the full time of one person.

u. Manufacturing and Quality Control

There are basically two types of costs presented here: The primary manufacturing and quality control costs, which include labor and materials for the system test and flight hardware for field spares, and for the

RE-ORDER No. 64-525

hardware consumed by subsystem qualification testing. In addition, a factor of 20 percent has been allowed for scrap and manufacturing losses, including subsystem and system attrition.

The second type of costs are those related specifically to the monitoring of manufacturing activities by the people engaged in the development of hardware subsystems. Thus the cost of interfacing between manufacturing elements and the developers of subsystems is carried here as a manufacturing cost.

v. Ground Support Equipment

This estimate includes costs for both electrical and mechanical GSE, used for both system development testing and flight hardware support. GSE costs for subsystem development use has in each case been included in those areas. The costs included here include basic labor, materials, special test equipment for GSE development, and subcontracts.

w. System Testing

There are five separate systems tests costed here and in each case, the costs of the spacecraft being tested are included under manufacturing and quality control.

In the case of the temperature control test, the contractor costs cover personnel, special test equipment and computer time, and the subcontractor costs cover space chamber rental.

The system integration and life test costs cover labor and special test equipment and the greatest single cost is for the rental of a space chamber for the life test for a period of nearly 1 year.

Structural system testing costs include principally labor and special test equipment.

Type approval testing also covers basically labor and special test equipment, the subcontractor cost being for a space chamber. Schedule for this test and the life test could possibly overlap, so that special attention should be directed to scheduling this area, in the event that the same chamber is to be used.

The sterilization assay concerns the lander only, and the costs include labor, materials for culturing, and filtration. The cost of renting a sterile facility has been assumed to be covered in the labor overhead applied to the site of the assay.

x. Acceptance Testing

This estimate includes costs for labor required to perform the test, special test equipment and materials.

y. Reliability and Quality Assurance

For both of these efforts the principal cost is labor. There are some material costs associated with quality assurance, however, and subcontract costs associated with reliability, which account for the subcontractor position of liaison costs during and following the subsystem development program.

z. Documentation

This estimate covers the labor and materials required to publish the documentation expected in a program of this size. The cost does not include any of the engineering effort required to author any of the documentation.

aa. Program Management

This estimate covers the labor expenses of a small project-type management system composed of six Project Engineers, reporting to a Project Manager, who is assumed to be overhead and not costed here. All other specific managerial tasks have been costed in their respective areas, such as final design, or reliability.

3.3 DETAILED COST PLAN

Included in the Section are detailed cost breakdowns of each line item of the summary sheets in the previous Section, shown in Figures 61 through 92.

These sheets are divided into two main sections, for bus and lander, each of which covers development and hardware costs, as well as in-house, or prime contractor costs, and outside, or subcontractor costs. The difference between development and hardware costs has been discussed above, both in the Introduction to this section and in the plan summary and therefore needs no further amplification here.

The difference between in-house and outside costs is defined as follows: There are three general categories of outside costs: materials, special test equipment, and subcontracts. The outside category as defined here covers only subcontracts. All costs associated with materials, special test equipment, and any purchased or vendor items, are considered to be prime contractor costs. For example, in the case of manufacturing and quality control, no outside costs are shown because none of the manufacturing processes are assumed to be subcontracted, and the subsystem development liaison costs are assumed in all cases to be borne by the prime contractor and not by any subsystem contractor.

A significant item worth pointing out here is the existence of "development" costs associated with the 1971 launch though by ground rule, no hardware development is considered for that launch. These costs do not, in fact, cover hardware development, but rather cover other nonhardware costs such as program management, documentation, reliability follow-on, and so forth.

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development	1,606								1,606
Hardware	-								-
Total	1,606								1,606
In-House Subtotal	1,606								1,606
Outside Subtotal	-								-
1971 Launch									
Development	N/A								
Hardware									
Total									
In-House Subtotal									
Outside Subtotal									
LANDER:									
1969 Launch									
Development	791								791
Hardware	-								-
Total	791								791
In-House Subtotal	791								791
Outside Subtotal	-								-
1971 Launch									
Development	N/A								
Hardware									
Total									
In-House Subtotal									
Outside Subtotal									

Figure 61 PRELIMINARY DESIGN (FOR TWO COMPETING CONTRACTOR CANDIDATES)

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development		411	571	646	397	77			2,102
Hardware		337	469	529	326	63			1,724
Total		748	1,040	1,175	723	140			3,826
In-House Subtotal		748	1,040	1,175	723	140			3,826
Outside Subtotal		-	-	-	-	-			-
1971 Launch									
Development				78	234	544	426	115	1,397
Hardware				64	191	446	349	95	1,145
Total				142	425	990	775	210	2,542
In-House Subtotal				142	425	990	775	210	2,542
Outside Subtotal				-	-	-	-	-	-
LANDER:									
1969 Launch									
Development		328	487	341	289	102			1,547
Hardware		268	398	280	237	83			1,266
Total		596	885	621	526	185			2,813
In-House Subtotal		596	885	621	526	185			2,813
Outside Subtotal		-	-	-	-	-			-
1971 Launch									
Development				85	216	344	256	123	1,024
Hardware				70	177	282	209	101	839
Total				155	393	626	465	224	1,863
In-House Subtotal				155	393	626	465	224	1,863
Outside Subtotal				-	-	-	-	-	-

Figure 62 SYSTEMS ANALYSIS--INTEGRATION AND FIELD SUPPORT

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development	1,816	2,070	1,520	795					6,201
Hardware	N/A								
Total	1,816	2,070	1,520	795					6,201
In-House Subtotal	1,816	2,070	1,520	795					6,201
Outside Subtotal	-	-	-	-					-
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
LANDER:									
1969 Launch									
Development	791	2,640	1,641	286	94	56			5,508
Hardware	N/A								
Total	791	2,640	1,641	286	94	56			5,508
In-House Subtotal	791	2,640	1,641	286	94	56			5,508
Outside Subtotal	-	-	-	-	-	-			-
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									

Figure 63 FINAL DESIGN

64-525

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development		1,380	685						2,065
Hardware	N/A								
Total		1,380	685						2,065
In-House Subtotal		1,335	662						1,997
Outside Subtotal		45	23						68
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
LANDER:									
1969 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									

Figure 64 BUS--TV SUBSYTEM HARDWARE DEVELOPMENT

RE ORDER No. 64-525

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development Hardware	N/A	405	53	39	10				507
Total		405	53	39	10				507
In-House Subtotal		332	43	32	8				415
Outside Subtotal		73	10	7	2				92
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
LANDER:									
1969 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									

Figure 65 BUS PAYLOAD PLATFORM HARDWARE DEVELOPMENT

RE-ORDER No. 64-525

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development		2,787	437						3,224
Hardware	N/A								
Total		2,787	437						3,224
In-House Subtotal		1,867	292						2,159
Outside Subtotal		920	145						1,065
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
LANDER:									
1969 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									

Figure 66 BUS COMMUNICATION AND POWER--HARDWARE DEVELOPMENT

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development		1,122	1,320						2,442
Hardware	N/A								
Total		1,120	1,320						2,442
In-House Subtotal		963	1,131						2,094
Outside Subtotal		159	189						348
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
LANDER:									
1969 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									

Figure 67 BUS ATTITUDE CONTROL HARDWARE DEVELOPMENT

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development		2,240	1,600						3,840
Hardware	N/A								
Total		2,240	1,600						3,840
In-House Subtotal		780	560						1,340
Outside Subtotal		1,460	1,040						2,500
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
LANDER:									
1969 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									

Figure 68 BUS PROPULSION HARDWARE DEVELOPMENT

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development		330	350	117					797
Hardware	N/A								
Total		330	350	117					797
In-House Subtotal		125	132	44					301
Outside Subtotal		205	218	73					496
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
LANDER:									
1969 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									

Figure 69 BUS TEMPERATURE CONTROL HARDWARE DEVELOPMENT

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development		1,550	580						2,130
Hardware	N/A								
Total		1,550	580						2,130
In-House Subtotal		1,550	580						2,130
Outside Subtotal		-	-						-
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
LANDER:									
1969 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									

Figure 70 BUS/LANDER SEPARATION HARDWARE DEVELOPMENT

RE-ORDER No. 64-525

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development		17	17	17					51
Hardware	N/A								
Total		17	17	17					51
In-House Subtotal		17	17	17					51
Outside Subtotal		-	-	-					-
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
LANDER:									
1969 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									

Figure 71 BUS SCIENTIFIC LIAISON HARDWARE DEVELOPMENT SUPPORT

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
LANDER:									
1969 Launch									
Development		892							892
Hardware	N/A								
Total		892							892
In-House Subtotal		492							492
Outside Subtotal		400							400
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									

Figure 72 LANDER AERODYNAMICS HARDWARE DEVELOPMENT SUPPORT

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
LANDER:									
1969 Launch									
Development		2,663	333						2,996
Hardware	N/A								
Total		2,663	333						2,996
In-House Subtotal		1,223	153						1,376
Outside Subtotal		1,440	180						1,620
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									

Figure 73 LANDER COMMUNICATION AND POWER HARDWARE DEVELOPMENT

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
LANDER:									
1969 Launch									
Development		548	430						978
Hardware	N/A								
Total		548	430						978
In-House Subtotal		548							978
Outside Subtotal									
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									

Figure 74 LANDER STRUCTURES HARDWARE DEVELOPMENT

RE-ORDER No. 64-525

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
LANDER:									
1969 Launch									
Development		1,116	420	33	3	3			1,575
Hardware	N/A								
Total		1,116	420	33	3	3			1,575
In-House Subtotal		1,084	407	32	3	3			1,529
Outside Subtotal		32	13	1	0	0			46
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									

Figure 75 LANDER THERMODYNAMICS AND MATERIALS HARDWARE DEVELOPMNET

ORDER No. 64-525

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
LANDER:									
1969 Launch									
Development		1,990							1,990
Hardware	N/A								
Total		1,990							1,990
In-House Subtotal		1,430							1,430
Outside Subtotal		560							560
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									

Figure 76 LANDER PARACHUTE HARDWARE DEVELOPMENT

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
LANDER:									
1969 Launch									
Development		1,833							1,833
Hardware	N/A								
Total		1,833							1,833
In-House Subtotal		1,593							1,593
Outside Subtotal		240							240
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									

Figure 77 LANDER IMPACT HARDWARE DEVELOPMENT

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
LANDER:									
1969 Launch									
Development		421	421						842
Hardware	N/A								
Total		421	421						842
In-House Subtotal		121	121						242
Outside Subtotal		300	300						600
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									

Figure 78 LANDER PROPULSION HARDWARE DEVELOPMENT

64-525

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
LANDER:									
1969 Launch									
Development		245	155	99					499
Hardware	N/A								
Total		245	155	99					499
In-House Subtotal		217	139	88					444
Outside Subtotal		28	18	11					55
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									

Figure 79 LANDER TEMPERATURE CONTROL HARDWARE DEVELOPMENT

RE-[illegible] No. 64-575

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
LANDER:									
1969 Launch									
Development	2,700	1,800	1,800						6,300
Hardware	N/A								
Total	2,700	1,800	1,800						6,300
In-House Subtotal	2,700	1,800	1,800						6,300
Outside Subtotal									
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									

Figure 80 LANDER STERILIZATION HARDWARE DEVELOPMENT

64-525

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
LANDER:									
1969 Launch									
Development		27	27	26					80
Hardware	N/A								
Total		27	27	26					80
In-House Subtotal		27	27	26					80
Outside Subtotal									
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									

Figure 81 LANDER SCIENTIFIC LIAISON HARDWARE DEVELOPMENT SUPPORT

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development		4,488	9,248	2,864	248				16,848
Hardware		3,668	7,626	2,353	210				13,857
Total		8,156	16,874	5,217	458				30,705
In-House Subtotal		8,156	16,874	5,217	458				30,705
Outside Subtotal									
1971 Launch									
Development				238	2,028	937	114	8	3,325
Hardware				964	9,155	3,750	455	34	14,358
Total				1,202	11,183	4,687	569	42	17,683
In-House Subtotal				1,202	11,183	4,687	569	42	17,683
Outside Subtotal									
LANDER:									
1969 Launch									
Development		1,876	3,589	1,692	200				7,357
Hardware		1,540	2,941	1,379	163				6,023
Total		3,416	6,530	3,071	363				13,380
In-House Subtotal		3,416	6,530	3,071	363				13,380
Outside Subtotal									
1971 Launch									
Development				35	723	480	93	5	1,336
Hardware				144	3,417	1,925	373	21	5,880
Total				179	4,140	2,405	466	26	7,216
In-House Subtotal				179	4,140	2,405	466	26	7,216
Outside Subtotal									

Figure 82 MANUFACTURING AND QUALITY CONTROL

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development		2,390	1,018	426	74				3,908
Hardware		590	252	106	18				966
Total		2,980	1,270	532	92				4,874
In-House Subtotal		2,580	938	532	92				4,142
Outside Subtotal		400	332						732
1971 Launch									
Development					41	18	4		63
Hardware					163	72	17		252
Total					204	90	21		315
In-House Subtotal					204	90	21		315
Outside Subtotal									
LANDER:									
1969 Launch									
Development		1,630	900	438	76				3,044
Hardware		346	192	93	16				647
Total		1,976	1,092	531	92				3,691
In-House Subtotal		1,976	1,092	531	92				3,691
Outside Subtotal									
1971 Launch									
Development					5	4	2		11
Hardware					18	14	7		39
Total					23	18	9		50
In-House Subtotal					23	18	9		50
Outside Subtotal									

Figure 83 GROUND SUPPORT EQUIPMENT

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development Hardware	N/A	197	397	65					659
Total		197	397	65					659
In-House Subtotal		47	97	65					209
Outside Subtotal		150	300						450
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
LANDER:									
1969 Launch									
Development Hardware	N/A	39	75	29					143
Total		39	75	29					143
In-House Subtotal		22	42	29					93
Outside Subtotal		17	33						50
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									

Note: Test units are costed under Mfg. and QC above
GSE is costed under GSE above

Figure 84 SYSTEM TESTING--TEMPERATURE CONTROL

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development Hardware			187	1,505					1,692
Total			187	1,505					1,692
In-House Subtotal			187	275					462
Outside Subtotal				1,230					1,230
1971 Launch									
Development Hardware									
Total									
In-House Subtotal									
Outside Subtotal									
LANDER:									
1969 Launch									
Development Hardware			93	750					843
Total			93	750					843
In-House Subtotal			93	135					228
Outside Subtotal				615					615
1971 Launch									
Development Hardware									
Total									
In-House Subtotal									
Outside Subtotal									

Note: Test units are costed under Mfg. and QC above
GSE is costed under GSE above

Figure 85 SYSTEM TESTING--SYSTEMS INTEGRATION AND LIFE TEST

RE-ORDER No. 64-525

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development			250						250
Hardware	N/A								
Total			250						250
In-House Subtotal			250						250
Outside Subtotal									
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
LANDER:									
1969 Launch									
Development			244						244
Hardware	N/A								
Total			244						244
In-House Subtotal			244						244
Outside Subtotal									
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									

Note: Test units are costed under Mfg. and QC above
GSE is costed under GSE above

Figure 86 SYSTEM TESTING--STRUCTURAL

RE-ORDER No. 64-525

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development		14	420	63					497
Hardware	N/A								
Total		14	420	63					497
In-House Subtotal		14	220	63					297
Outside Subtotal			200						200
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
LANDER:									
1969 Launch									
Development		12	344	49					405
Hardware	N/A								
Total		12	344	49					405
In-House Subtotal		12	144	49					205
Outside Subtotal			200						200
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									

Note: Test units are costed under Mfg. & QC above
GSE costed under GSE above

Figure 87 SYSTEM TESTING--TYPE APPROVAL (PTM)

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
1971 Launch									
Development	N/A								
Hardware	N/A								
Total									
In-House Subtotal									
Outside Subtotal									
LANDER:									
1969 Launch									
Development		429							429
Hardware	N/A								
Total		429							429
In-House Subtotal		—							—
Outside Subtotal		429							429
1971 Launch									
Development						429			429
Hardware	N/A								
Total						429			429
In-House Subtotal						-			-
Outside Subtotal						429			429

Note: Test unit costed under Mfg. & QC above
GSE costed under GSE above

Figure 88 SYSTEM TESTING--STERILIZATION ASSAY

RE-ORDER No 64-525

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development			280	280					560
Hardware			230	230					460
Total			510	510					1,020
In-House Subtotal			510	510					1,020
Outside Subtotal			-	-					-
1971 Launch									
Development						102			102
Hardware						408			408
Total						510			510
In-House Subtotal						510			510
Outside Subtotal						-			-
LANDER:									
1969 Launch									
Development			170	170					340
Hardware			140	140					280
Total			310	310					620
In-House Subtotal			310	310					620
Outside Subtotal			-	-					-
1971 Launch									
Development						62			62
Hardware						248			248
Total						310			310
In-House Subtotal						310			310
Outside Subtotal						-			-

Figure 89 ACCEPTANCE TESTING

ORDER N 64-525

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development Hardware	N/A	1,237	1,296	553	106	2			3,194
Total		1,237	1,296	553	106	2			3,194
In-House Subtotal		1,107	1,204	509	100	2			2,922
Outside Subtotal		130	92	44	6				272
1971 Launch									
Development Hardware	N/A			54	100	69	49		272
Total				54	100	69	49		272
In-House Subtotal				45	85	60	45		235
Outside Subtotal				9	15	9	4		37
LANDER:									
1969 Launch									
Development Hardware	N/A	713	732	305	32	2			1,784
Total		713	732	305	32	2			1,784
In-House Subtotal		676	699	290	30	2			1,697
Outside Subtotal		37	33	15	2				87
1971 Launch									
Development Hardware	N/A			50	106	67	47		270
Total				50	106	67	47		270
In-House Subtotal				39	82	53	39		213
Outside Subtotal				11	24	14	8		57

Figure 90 RELIABILITY AND QUALITY ASSURANCE

64-525

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development		86	123	123					332
Hardware	N/A								
Total		86	123	123					332
In-House Subtotal		86	123	123					332
Outside Subtotal		—	—	—					—
1971 Launch									
Development					70	70	90		230
Hardware	N/A								
Total					70	70	90		230
In-House Subtotal					70	70	90		230
Outside Subtotal					—	—	—		—
LANDER:									
1969 Launch									
Development		106	145	142					393
Hardware	N/A								
Total		106	145	142					393
In-House Subtotal		106	145	142					393
Outside Subtotal		—	—	—					—
1971 Launch									
Development					38	38	47		123
Hardware	N/A								
Total					38	38	47		123
In-House Subtotal					38	38	47		123
Outside Subtotal					—	—	—		—

Figure 91 DOCUMENTATION

	1965	1966	1967	1968	1969	1970	1971	1972	Total
BUS:									
1969 Launch									
Development Hardware	N/A	63	85	49	14				211
Total		63	85	49	14				211
In-House Subtotal		63	85	49	14				211
Outside Subtotal		-	-	-	-				-
1971 Launch									
Development Hardware	N/A			35	70	41	14		160
Total				35	70	41	14		160
In-House Subtotal				35	70	41	14		160
Outside Subtotal				-	-	-	-		-
LANDER:									
1969 Launch									
Development Hardware	N/A	83	113	66	18				280
Total		83	113	66	18				280
In-House Subtotal		83	113	66	18				280
Outside Subtotal		-	-	-	-				-
1971 Launch									
Development Hardware	N/A			44	86	52	18		200
Total				44	86	52	18		200
In-House Subtotal				44	86	52	18		200
Outside Subtotal				-	-	-	-		-

Figure 92 PROGRAM MANAGEMENT

RE-ORDER No. 64-525

4.0 GLOSSARY OF TERMS

The following list contains brief definitions of some of the more significant terms appearing repeatedly throughout the volume.

1. Preliminary Design

The activity which initiates the hardware program - involves two contractors competing for the prime award, and results in preliminary layouts, preliminary subsystems requirements, and mission analyses based on the design. The activity ends with the choice of one contractor or the winner, at which time the final design effort is started.

2. Final Design

The continuation of preliminary design, principally involving subsystem design integration and system design synthesis, follow on and testing support.

3. Component

Parts which go together to form subsystems.

4. Subsystem

A group of components comprising a major subassembly of either the bus or lander.

5. System

The bus, lander, or combination of both.

6. Subsystem Development Program

A hardware development activity, the purpose of which is to provide a subsystem for either the bus or lander. An example is the parachute program for the lander, the purpose of which is to supply parachutes and deployment mechanisms comprising the parachute subsystem.

7. Type Approval Testing

For the 1969 launch opportunity a total of nine spacecraft vehicles will be fabricated, five for system testing and four for flights and spares. The type approval test is the system test performed on the number four system test vehicle, and is the most critical system test in that it qualifies the subsequent spacecraft for flight. In addition, this test is a controlling schedule item, as explained in the development plan. The spacecraft used for this test is often referred to as the PTM unit.